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GEOGRAPHIC VARIATION IN MORPHOLOGY OF SPOTTED AND SPINNER DOLPHINS (Stenella attenuata and S. longirostris) FROM THE EASTERN TROPICAL PACIFIC

by

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DOLPHINS (STENELLA ATTENUATA AND S. LONGIROSTRIS) FROM
THE EASTERN TROPICAL PACIFIC

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ABSTRACT

Two dolphin species--Stenella attenuata and S. longirostris--commonly associated with the tuna fishery are widely distributed in the eastern tropical Pacific Ocean. A re-analysis of morphological characteristics is warranted, given the increased number of specimens now available. Thus, a study was completed involving 36 measures of skull characteristics and total body length. Numerous univariate and multivariate procedures were employed to assess geographic variation in each of the species and to make interspecific comparisons of character trends. Variation patterns were also evaluated with respect to geographic patterns of 14 environmental variables.

In an analysis of geographic location and seasonal variation for S. attenuata, we found significant interactions for 28% of the skull measures. While none of the characters exhibited significant seasonal variation within localities, all showed substantial geographic variation. Since sexual dimorphism was evident in 64% of the skull characters, we applied correction factors to all measurements in order to combine all data into a single analysis and, at the same time, to take into account such dimorphism. An initial analysis indicated striking differences involving all characters between onshore and offshore S. attenuata, which corresponded to the distinction between S. attenuata graffmani and other forms. Further investigations involving offshore S. attenuata indicated a strong subdivision between northern and southern populations; in addition, samples from westerly locations were substantially different from the others studied. In general clinal variations in many of the characters followed similar changes in environmental variables. The highest correspondence was of the width of the temporal fossa with sea surface temperature in July. In addition, the thickness of the oxygen minimum

layer showed a variation pattern that is statistically associated with 58% of the skull characters. Total lengths did not show strong spatial patterning. However, differences between northern and southern populations were evident, as were those between onshore and offshore samples.

Seasonal variation and geographic position were also analyzed for S. longirostris. Only two characters showed interactive effects, and none exhibited a significant seasonal component. Sexual dimorphism was demonstrated for 13 of 36 morphological characters. While sexual dimorphism showed very similar trends in S. attenuata and S. longirostris, it was less pronounced in the latter species. Corrections of all characters were made on all specimens to take into account sexual differences. Geographic variation was evident in all characters, with the most significant differences being between northern and southern populations, and between a close-to-shore Costa Rican form and the other populations. More westerly populations sometimes grouped with those from the north and at other times with populations from the south. Many morphological characters had geographic patterns of variation that corresponded closely with those of environmental variables. Solar insolation values for January showed a concordance with the patterns of 69% of the characters analyzed. Many morphological features (77%), particularly widths, had strong inverse associations with the sea surface temperature in July. Body lengths were longer south of the equator than in northern areas.

Extensive covariation was found between S. attenuata and S. longirostris, possibly indicating common responses to environmental differences. However, in some cases, such as with measurements of the temporal fossa, inverse relationships were found. Variation in body size was negatively associated for the two species.

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INTRODUCTION

Most organisms vary geographically in a number of characteristics, including those involving morphology, physiology, and behavior. Geographic variation has been studied extensively in animals (see review of earlier literature by Gould and Johnston 1972), and a variety of statistical techniques have been employed to facilitate our understanding of the underlying bases of geographic patterns. The discerning and elucidation of geographic patterns is of course of intrinsic interest to evolutionary biologists and systematists, and prerequisite to a further understanding of basic evolutionary processes. In addition, accurate information on spatial variation can be of considerable value to other biologists, particularly those involved in resource management.

Earlier studies of geographic variation in dolphins (Perrin 1972, 1975a, 1975b, Perrin, Sloan and Henderson 1979) have demonstrated geographic variation in external morphometric and color characteristics. These studies have provided the basis for use of stock units in assessment and management of these species. In recent years, numerous additional specimens have become available and these provide the basis for a re-analysis of geographic variation of the spotted and spinner dolphins (Stenella attenuata and S. longirostris) in the eastern tropical Pacific. Therefore, we have re-evaluated geographic variation patterns

in these two species using a variety of univariate and multivariate techniques. Morphometric measures and tooth counts were taken from skulls and mandibles, and a large data set was available of total body lengths. The approaches used include some that have been employed in the previous investigations in addition to a number of relatively new methods that have not been applied in past studies of dolphins. Through this investigation we have provided information which can be used to further define geographical stocks in a way that management units can be refined.

MATERIALS AND METHODS

Skull Measurements

Figure 1 is a flow chart summarizing the analyses conducted involving skulls and mandibles of S. attenuata and S. longirostris. Details of our procedures are given below. We attempted to locate all museum specimens involving skulls and mandibles of adult dolphins of these two species from the eastern tropical Pacific Ocean. Age status was determined using the criterion of Dailey and Perrin (1973). Individual skulls were considered to be from adults if they exhibited distal fusion of the premaxillaries and maxillaries.

Specimens were assigned to 5° latitude-longitude blocks (see Figs. 2 and 3). More specific collecting localities for S. attenuata are depicted in Fig. 4 for northeastern blocks. When it appeared likely that a beached animal was involved, we deleted the specimen from our study. Also, we did not consider specimens where, because of their physical condition, it was not possible to obtain essentially all of the measurements taken on other specimens.

Each geographic block has been given a numerical code represented on the left and lower margins of our distribution maps (see Fig. 2). For example, a specimen from a locality 6°N, 107°W was assigned to block 0504. The 5° block size was selected because it was judged that sample sizes available would not permit detailed analysis of smaller geographic units. Furthermore, since it was desirable to incorporate specimens from all seasons of the year in order to achieve adequate samples for statistical purposes, we felt that migratory movements and related factors were less likely to significantly influence results than if smaller sampling areas were used.

A series of 36 morphometric and meristic characters were measured on each specimen (Table 1 and Fig. 5). Most were selected from Perrin's (1975b) set of characteristics, with a few being added or slightly modified as a result of the experiences and suggestions of previous investigators. Since only specimens that were largely complete (i.e., undamaged) have been included in the study, there were relatively few measurements that could not be taken (less than 0.16% for S. attenuata and 0.53% for S. longirostris). The missing values were estimated by a linear regression ("Missing Data Estimator" program developed by Dennis M. Power) onto that character which explained the greatest proportion of the variance for the variable under consideration.

While most of the characters evaluated are influenced by age of the specimens, tooth counts (characters 29-32) are set at an early age. Therefore, these characters were analyzed twice, once based on adult specimens and a second time using larger samples that included all available animals.

We were interested in the relationship (if any) of environmental patterns in the eastern tropical Pacific and those of morphology. Therefore, environmental variation in the geographic ranges of these two dolphins was characterized using 14 variables (Table 2). Data sources are given in the table and summary values for each latitude-longitude block are given in Appendix 4. Because available information on eight of the variables (i.e., sea surface temperature in January, July, and annual variation; depth and thickness of oxygen minimum layer; thermocline depth in winter and annual variation; surface salinity) was incomplete in that it did not include measures for blocks 0503 and 0603, we employed the values for adjacent blocks as the best estimators of the environmental values. Source information for Thermocline Depth in Summer was lacking for so many

western blocks that this environmental variable was not used in the analysis of the data on total body lengths.

As an initial step, we conducted for each species a two-way analysis of variance for each character of geographic block and season. Specimens were divided into those taken in winter (October-March) or in the summer (April-September). Data from any block with at least two winter and two summer specimens were included. This criterion was met by eight blocks for S. attenuata (Fig. 6) and seven for S. longirostris (Fig. 7).

In order to evaluate possible morphological differences between sexes, we also conducted a two-way analysis of variance for each character, with the two factors being block and sex. For S. attenuata, the analysis was conducted using the 11 blocks with at least five males and five females (Fig. 2), whereas we used the 9 blocks for S. longirostris where four or more specimens of each sex were available (Fig. 3).

As is indicated in the section on results, significant sexual dimorphism was found for many of the 36 characters in each of the species. Thus, so that we could utilize all specimens in the same analysis, a correction term for sex was applied for all characters. Within a species, all measurements for a particular character of specimens representing the smaller sex were adjusted upward, while those for the larger sex were lowered an equal amount. The extent of the correction depended on the degree of dimorphism. We computed the difference between males and females for each character within each of 11 blocks for S. attenuata and 9 blocks for S. longirostris. In order to obtain an average difference between sexes of a species, we calculated a weighted mean of the within-block differences for a species. The weighting factor for each block was the geometric mean of the number of males and number of females for that block. The correction factor was one-half of the weighted difference. The

character value for each specimen in the analysis was adjusted accordingly, depending on the animal's sex. The adjusted measures were combined for all subsequent analyses. Given that there is not a commonly used term to refer to such "non-sex" or "sex-adjusted" specimens or specimen values, we have employed the term "zwitter" (from the German word for hermaphrodite or hybrid) to identify them.

After conversion to zwitter, block means were computed for each character (see Appendices 1.01 to 1.36 for S. attenuata and Appendices 2.01 to 2.36 for S. longirostris for data on adult animals; tooth count averages for all specimens are given in Appendices 1.37 to 1.40 and Appendices 2.37 to 2.40, respectively, for the two species). The means for the 36 characters (as indicated in Appendices 1.01-1.36 and 2.01-2.36) were employed in subsequent principal component and cluster analyses. First, within each species the characters were standardized, so that the mean of a character for all blocks was zero and the standard deviation one. The phenetic relationships of the blocks can be graphically represented as scatter diagrams of blocks plotted with respect to the first few principal components extracted from a matrix of correlations among characters (Sneath and Sokal 1973). These components can be considered to be a set of new orthogonal axes in the 36-dimensional character space. Since a number of the characters are correlated, it is possible to describe much of the interblock variation in terms of a few "new" coordinate axes. Blocks are projected onto these components and can be represented as two-dimensional plots or three-dimensional models. Such representations are useful in that, if clusters of similar blocks are found in the data, they will be evident in the graphical representations; however, no assumption is made about clusters being present, and gradual trends in variation can also be depicted well by such techniques.

Hierarchical cluster analyses were also performed. In one set of analyses, average distance coefficients (Sneath and Sokal 1973) were calculated for all pairs of blocks based on the standardized data. The unweighted pair-group method using arithmetic averages (UPGMA) was employed as the clustering algorithm. Cophenetic correlation coefficients were computed to indicate the degree to which distances in the resulting dendrogram accurately represented the original interblock distances.

Another type of hierarchical cluster analysis was also used--the linear adaptive hierarchical clustering scheme (AHCS) described by Rohlf (1970; Sneath and Sokal 1973). This technique is particularly useful when elongate or non-hyperspheroidal clusters are present. Since the linear AHCS is impractical with large numbers of characters, the analysis was performed only on the first few principal components, which summarize much of the character variation among blocks. This approach uses an artificial variance-covariance matrix for each block to be clustered. A value for W of 1.0 (see Rohlf, Kishpaugh, and Kirk 1979 and Rohlf 1970 for further explanation) was used.

We also obtained clustering results using a non-hierarchical K-group method called function-point cluster analysis (Katz and Rohlf 1973) on standardized data. Blocks are assigned to a series of subgroups at a specified level. A hierarchical (but not necessarily non-overlapping) system of clusters can be obtained by performing and considering the analysis at more than one clustering level. Non-hierarchical clusters, if useful indicators of associations among blocks, might be of particular value in the evaluation of possible management units. The particular program is described by Rohlf et al. (1979). The value for the w parameter used by the function-point clustering method was varied.

As is indicated in the Results section, distinctive clusters were

found that resulted in the separation of offshore and onshore S. attenuata. Thus, blocks for these two groups were treated separately in subsequent analyses. Some of the techniques mentioned above were also used to evaluate within-block variation in this species, since there was a chance that onshore and offshore specimens could have been assigned to the same block.

A one-way analysis of variance was performed for each character, comparing specimens of offshore and onshore S. attenuata. This indicated which characters showed significant differences between offshore and onshore forms. In order to determine which set of characters in combination would give the best discrimination between members of these two forms, we conducted a step-wise discriminant analysis. The specimens were divided into the two groups and the step-wise discriminant analysis (Program P7M of BMDP-79; Dixon and Brown 1979) used to find the linear combination of the the variables that best characterizes the differences between these two forms. Plots of projections onto the canonical variable were prepared. For some specimens, we were unsure as to whether they represented onshore or offshore S. attenuata. Therefore, they were not used in the initial discriminant analysis, but subsequently were projected onto the discriminant axis in order to determine their correct allocation. Also, we treated in a similar way four specimens that were the sole representatives of blocks that potentially could have contained onshore animals.

The step-wise discriminant analysis was also used to determine that set of variables which show the greatest degree of geographic variation--in this case referring to those characters that provide the greatest interblock separation relative to the degree of intrablock variation. This analysis was applied to offshore S. attenuata and to S. longirostris.

Plots of the first two canonical variables show the maximum spread of the blocks in two-dimensional space. The original variables, which in combination exhibited the maximum interblock variability, were then subjected to additional, more detailed analyses.

Product-moment correlations among characters were computed. In addition, we calculated correlations of characters with environmental variables based on block means to assess covariation and to determine whether single morphological variables showed patterns that might be closely linked with variation in the environment.

Using a test devised by Mantel (1967) and described by Sokal (1979), we analyzed interlocality variation in each character to determine whether character values are geographically patterned or vary spatially at random. This procedure enabled us to determine whether differences in character values between all pairs of samples are statistically associated in a linear manner with the corresponding geographic distances. The observed association between sets of character differences and geographic distances was tested relative to their permutational variance, and the resulting statistic was compared against a Student's t-distribution with infinite degrees of freedom. Computations were performed with GEOVAR, a library of computer programs for geographic variation analysis written by David M. Mallis and furnished by Robert R. Sokal.

Character differences were compared first with the actual geographic distances (in nautical miles) between the centers of blocks and then with the reciprocals of the distances. In evaluations employing the reciprocals of distances, all the larger distances are considered to be effectively equal, and the portion of the scale involving smaller distances is expanded. Thus, the use of reciprocals of distances increases the power of the analysis to reveal geographic patterns that are local in nature (i.e.,

involving closely placed blocks), whereas tests involving actual distances evaluate regional trends. Positive associations of character differences and actual geographic distances are indicated by positive t-values, while negative t-values denote such associations when reciprocals of distances are used.

We also computed matrix correlations (Sneath and Sokal 1973) between character differences and the associated geographic distances or reciprocals of distances between localities. The significance of these coefficients cannot, however, be tested in the conventional way, because all pairs of localities were used and these are not statistically independent. The resulting values are useful as descriptive statistics indicating the degree of association of difference values.

In addition to using matrix correlations and the Mantel procedure to test for the presence of local and regional patterning of variation in individual characters, we evaluated degrees of concordance of difference patterns involving principal components (projections based on morphological characters) versus environmental variables, as well as the discriminating morphological variables versus environmental variables. In these tests, differences between each pair of blocks in one variable were compared with those for a second variable.

Total Body Lengths

Total body lengths for adult animals were analyzed for S. attenuata and S. longirostris considering the sexes separately. Average lengths and sample sizes for male and female S. attenuata are presented in Appendices 3.01 and 3.02, respectively, while similar data are summarized in Appendices 3.03 and 3.04 for S. longirostris. Only blocks with five or more measurements for a given sex were considered.

Data were from those summarized on life history forms and maintained at the Southwest Fisheries Center. Females in our samples had at least one ovarian scar (regardless of whether information was available on only one or both ovaries). Male S. attenuata were included if either testis had a weight of 100 g or greater. A value of 94 g or greater was used for S. longirostris. Growth and development have been discussed in detail by Perrin (1975b), as well as more recently by Perrin, Coe, and Zweifel (1976) for S. attenuata and Perrin, Holts, and Miller (1977) and Perrin and Henderson (1979) for S. longirostris.

RESULTS FOR STENELLA ATTENUATA

Seasonal Variation

For S. attenuata, the two-way analyses of variance to test for the effects of block (geographic location) and season (winter versus summer) indicated there were significant interaction effects for 10 of the 36 characters, with character numbers and levels of significance (*, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$) as follows: (9) Preorbital W.*; (10) Postorbital W.**; (11) Skull W.(at Zygomatic P.)**; (20) W. Temporal Fossa**; (24) W. Internal Nares***; (27) W. at Pterygo. Sutures**; (34) Ht. Ramus**; (35) Tooth W.**; (36) L. Ramus***. The interaction effects suggest that the degree of seasonal differences varies with geographic location for these 10 characters. While all 36 characters included very highly significant differences with respect to variation among blocks, none showed statistically significant differences between winter and summer. Thus, specimens were not further analyzed or "corrected" for this factor.

Sexual Dimorphism

A similar two-way analysis of variance was employed to assess sexual dimorphism. Sufficient numbers of males and females for intrablock comparisons were available for 11 blocks. Significant ($P < 0.05$) interactive effects between block and sex factors were found for five characters: (1) Condylbasal L.; (5) W. Rostrum(at 1/4 L.); (6) W. Rostrum(at 1/2 L.); (24) W. Internal Nares; and (27) W. at Pterygo. Sutures. Sexual dimorphism was found for 23 of the 36 characters (Table 3), with differences often being substantial. As indicated in Table 3, females exhibited a longer rostrum and greater lengths in associated characters, while males were larger in most other characters. Because of the relatively high proportion of characters for which sexual differences were found, we corrected

measurements of all characters for individual animals in order to be able to use all specimens simultaneously in subsequent analyses. The correction terms applied are presented in Table 3 and are based on weighted (see section on methods) differences between sexes found within blocks. Block means of these zwitter values for S. attenuata are included in Appendix 1.

A two-way analysis of variance for sex and block completed after the correction terms were applied indicated that this procedure had been largely successful in removing differences due to sex from the data set. Only two characters--(8) W. Rostrum(at 3/4 L.) and (2) W. Temporal Fossa--still showed statistical differences ($P < 0.05$), representing a proportion of the total of 36 characters that could well be due to chance alone. Also, the following five characters showed significant interactive effects: (8) W. Rostrum(at 3/4 L.); (20) W. Temporal Fossa; (24) W. Internal Nares; (27) W. at Pterygo. Sutures; and (36) L. Ramus. Two of these characters (24 and 27) showed such effects in the initial analysis.

Geographic Variation

A principal component analysis of means for characters was done to assess whether there were any marked trends--geographic or other type--in these data. The first two principal components explained 83.5% of the total character variance (74.6% for I and 8.9% for II). Character loadings are presented in Table 4, and projections of the 23 blocks onto the two components are shown in Fig. 8. Clearly, there is a separation of four onshore localities (0804, 0508, 0509, 0510) from the remaining blocks with respect to component I. This corresponds to a differentiation between onshore and offshore populations as described by Perrin (1975a,b).

The four onshore blocks represented to the right of Fig. 8 have specimens that tend to be larger for all characters having high positive

loadings on component I (Table 4), which is the case for all characters except those involving the number of teeth (characters 29-32). These counts have a weak negative association with the first component. The second component separates the more northerly onshore block (0804) from the other three (Fig. 8) and is primarily associated with the four characters indicating number of teeth. Animals in block 0804 tend to have a greater number of teeth than do those from blocks 0508, 0509, and 0510.

Cluster analysis also showed a distinct dichotomy between onshore and offshore blocks. Figure 9 is a phenogram resulting from an analysis of average distance. Its cophenetic correlation coefficient of 0.97 indicates that this dendrogram very accurately portrays the phenetic associations among blocks. The primary division separates the four onshore blocks from the others. Within the onshore cluster, the more northerly block (0804) is shown to be the most different from the others. Some structure is evident within the cluster of offshore blocks, but these associations can be depicted best in analyses restricted only to offshore blocks (see below).

As indicated in Fig. 10, using the adaptive hierarchical clustering scheme also resulted in a marked separation of the onshore and offshore blocks. The general arrangement of blocks is very similar to that obtained from the unweighted pair group method of clustering.

The same data were subjected to the function-point clustering method, and the findings are shown in a generalized skyline diagram (Wirth et al. 1966) in Fig. 11. The w values indicate different levels of clustering and the resulting clusters are hierarchical, but need not be nested. In the skyline diagram, blocks represented by a single number (e.g., 1) on a particular vertical line are in the same cluster, while those with a blank in the skyline diagram are in a cluster by themselves. For example, at the w value of 6.08, all blocks are joined in a single cluster. When w is

5.62, blocks 0508 and 0509 are in one cluster and the rest of the blocks are in another. For the level with w at 3.78, blocks 0508, 0509, and 0510 are in one cluster, 0804 in another, and the remaining blocks form the third cluster. Overall, the separation of the four coastal from the noncoastal blocks is confirmed. Further analysis (i.e., extending computations to smaller w values) would reveal additional structure within the offshore group.

While the distinctiveness of the offshore versus the onshore forms is clear from the above analyses, we could not be certain that all specimens included in the four onshore blocks actually were members of onshore populations. Our grid-block system was established without regard to the location of possible taxonomic subdivisions and, thus, it would have been possible to incorporate a mixture of onshore and offshore specimens within single block. Therefore, we performed principal component and UPGMA cluster analyses on standardized data to aid in the identification of "misplaced" specimens. For these analyses, we used all of the specimens from onshore blocks (0508, 0509, 0510, 0804), as well as those from offshore blocks 0607 and 0705. The latter two had a substantial number of specimens (see Fig. 2), some of which could have represented the onshore type.

The principal component loadings for the individual specimens were essentially the same as those presented in Table 4 for the block means, with component I having high, positive correlations with all characters except tooth counts, while II had positive associations with the tooth counts. Projections (Fig. 12) implied that three of the specimens from onshore blocks (0508-21, 0508-41, 0509-31; museum numbers NMNH 395938, NMNH 487417, and NMNH 487610, respectively) were more appropriately classified as being from offshore populations. Two of these were clearly typical

offshore specimens, given their placements in the diagram, and the third was questionable in terms of its correct designation. The placement of two onshore specimens (0705-101 and 0705-103; museum numbers NMNH 395926 and NMNH 395928, respectively) in this two-dimensional plot also brought into question their affinities.

A cluster analysis (Fig. 13) of the individual specimens indicated a major subdivision separating onshore (above) and offshore (below) individuals. It further confirmed the conclusions from the component analysis as to the likely misclassification of the three specimens from onshore blocks (0508-21, 0508-41, 0509-31; these along with some others are marked with asterices in Fig. 13). In addition, the two specimens from block 0705 (101 and 103) with intermediate placements on component I in Fig. 12 are included in a cluster depicted at the bottom of the dendrogram (Fig. 13) along with 0705-102 (NMNH 395927) and 0804-54 (SWFC DJT045). This is the most distinctive subcluster of the offshore group. The placements of 0705-102 and 0804-54 have also been identified in the principal component diagram (Fig. 12).

Thus, as a result of these two analyses, a possible question was raised as to the correct designation of seven specimens (i.e., those identified in Figs. 12 and 13). Since discriminant analyses of most types are highly sensitive to the inclusion of "misclassified" individuals in the "known" groups, we deleted these specimens from subsequent characterizations of onshore and offshore forms. However, these specimens were later projected onto the discriminant function calculated to differentiate between the two forms (see below). We also redid all earlier analyses with these specimens deleted; no detectable differences in results were found.

With the demonstrated, general subdivision between onshore and

offshore S. attenuata, we proceeded with a characterization of these differences. A one-way analysis of variance (Table 5) between specimens of the two forms showed that there were statistical differences for all 36 characters employed in our studies. The specimen means in Table 5 show that the onshore S. attenuata are larger in all mensural characters and have slightly lower tooth counts than do their offshore counterparts.

A step-wise discriminant analysis was conducted to determine the combination of characters that would best differentiate between onshore and offshore specimens. For the canonical variable (which is equivalent to the discriminant function in the two-group case), we specified the F-value to enter as 4.0 and based the classification function on equal probability values for the two groups. The resulting function included nine characters (Table 6). The best character for differentiating between offshore and onshore specimens was Tooth W., with the second character entered into the function being Ht. Ramus. A plot (Fig. 14) of the specimens projected onto the canonical variable shows complete separation of offshore and onshore S. attenuata. Coefficients for the function are given in the fourth column of Table 6 and can be used to place unknown specimens onto this discriminant axis. An unknown's original measurements are corrected to provide zwitter values (see Table 3 for correction factors), these values are multiplied by the coefficients, the sum of the products is taken, and the constant listed in Table 6 is added. In Table 6, the classification functions for the two groups are included. Of the 605 specimens (574 offshore, 31 onshore) on which our analysis of offshore and onshore S. attenuata was based, all were correctly assigned using the classification functions.

The placement of unknown specimens into one or the other group can be done using a similar procedure to that described above for obtaining their projections onto the discriminant function. However, in this case, one

value is obtained for classifying the specimen as an offshore animal and another for onshore. The specimen should be assigned to the group for which the resulting classification value is the lower.

For the seven unknowns, two (0509-31, 0508-41) were classified as belonging to the offshore group, while the remaining five were assigned to the group of onshore specimens. Clearly, for purposes of our analysis it was appropriate to remove 0509-31 and 0508-41 from the onshore blocks (see their placements in Fig. 14), since they represent the offshore form. It does appear as if 0508-41 is a relatively typical onshore specimen. The other four specimens have projections intermediate between those of the known groups, although tending toward the onshore type (Fig. 14). In particular, 0705-102 and 0705-103 are intermediate in nature; based on the classification functions, the calculated probabilities for 0705-102 are 52.4% that it should be in the onshore group and 47.6% that it belongs to the offshore assemblage, while those for 0705-103 are 56.1% and 43.9%, respectively.

Four blocks (0706, 0410, 0409, 0309) that include portions of the main shoreline were represented by only single specimens (see Fig. 2). Museum numbers for these animals are NMNH 395929, NMNH 258641, ZMA 18737, and ZMA 18733, respectively. They were also projected onto the discriminant function axis to determine their correct allocation to the onshore or offshore type. Projection values for the individual specimens from these four blocks, which correspond to those depicted on the horizontal axis of Fig. 14 for the main samples, are as follows: 0706, 1.63; 0410, 4.71; 0409, -0.65; and 0309, 0.07. Classification functions clearly indicated (with 100% probability, given rounding error) that those from 0706, 0409, and 0309 are offshore specimens, while the one from 0410 is an onshore representative.

As an initial step in analyzing more intensively geographic variation in offshore S. attenuata, we conducted a principal components analysis using the means for the 19 offshore blocks. Character loadings are given in Table 7 and projections on the first two principal components in Fig. 15. The first component explained 43.2% of the total character variance, while the second accounted for 19.4% (62.6% cumulative). The third component primarily included characters that distinguished block 0306---which had a small sample size of only two---from the others; thus, we did not analyze it further.

The first component separates the more southerly localities and block 0501 from those to the north (Fig. 15). It is a general skull robustness factor with high positive loadings (i.e., over 0.6) on 19 of the 36 characters (Table 7); the two measurements of the temporal fossa (19 and 20) have negative associations with this component. Overall, the specimens from more southerly blocks tend to have larger skulls, while those from northern localities (and to the left of the diagram) exhibit smaller dimensions. Table 7 indicates that component II has 11 characters with negative correlations less than -0.5 and one (W. at Pterygo. Sutures) with a positive correlation over 0.5. The component has high negative associations with characters involving the number of teeth, length of the toothrow, and a variety of other characters. Those localities with negative projections onto II (Fig. 15) have high values for these characters. The most marked association (-0.927) of this component is with Skull W.(at Parietal). This characteristic reflects indirectly the depth of the temporal fossa, which is associated with major jaw muscles. On Fig. 15, a solid line has been drawn to encompass the southern localities, while the more northerly blocks are circumscribed with a dashed line. Some blocks like 0703 and 0606 deviate somewhat from others in their group.

Also, blocks 0403 and 0501, which represent localities to the southwest, are divergent. The former is portrayed on the basis of only two specimens, and its placement could change with a more adequate sample size. However, 0501 is represented by seven specimens and is obviously not most closely associated with the spatially adjacent, more northerly group of localities.

A cluster analysis of average distances using UPGMA (Fig. 16) for the 19 offshore blocks showed essentially the same results, with the exception that several localities were depicted as outliers. Apparently, in the total character space (in contrast to the first two principal component dimensions), these blocks demonstrate unique variation in one or more characters not necessarily heavily loaded on the initial two components. For example, block 0306 is shown as being the most divergent locality in Fig. 16, while in the component plot (Fig. 15) it is more closely associated with the other southern blocks; block 0306 is represented by only two specimens and the possibility that its deviant position in the dendrogram is a result of sampling should be considered. Not unexpectedly, given their placement in Fig. 15, the northern blocks 0606 and 0703 are separated, as are 0403 and 0501. Four of the five southern blocks are depicted as a distinctive group at the top of the phenogram.

Function-point clustering of distances provided a somewhat different perspective (Fig. 17), although one that is not too surprising given the distribution of blocks in the principal component plot (Fig. 15). Initial clusters of single blocks (0306, then 0403, 0501, 0703, 0206, and 0606) are separated from the main group. Many of these have already been identified as outliers and/or as having relatively small sample sizes. At the highest clustering levels depicted in Fig. 17, a grouping of northern blocks is retained, with all others forming their individual clusters. The principal component and the UPGMA cluster analyses also implied that these northern

blocks were morphologically very similar.

The offshore blocks were also investigated using canonical variates analysis, where one summarizes the maximum among-group character variance in a space of particular dimension. The F-value to enter was set at 2.0. Seven characters (Table 8) were incorporated into the analysis, with the resulting dispersion of block centroids on the first two canonical variables being as shown in Fig. 18. The eigenvalues for these two variables are 0.785 and 0.169, respectively; the two variables explain 80.3% of the total dispersion. Since the variables entered into this analysis are those that exhibit (in combination) the greatest relative variability among groups, they were judged to be the ones most likely to show associations with environmental variation. Thus, the first five entered (see appropriate column in Table 8) were analyzed in somewhat more detail than other individual characters.

The plot of the centroids for each of the blocks on the first two canonical variables (Fig. 18) shows a separation between southern (to the left) and northern blocks. The western block 0501 groups loosely with the southern localities, while 0403 is more closely allied with those from the north. As expected, given the continuous nature of dolphin geographic distributions, many of the blocks were very similar and, thus, it was not possible to unambiguously assign specimens to a particular block. However, seldom was a misclassification made of an individual from a northern block into a southern one or vice versa.

For offshore S. attenuata, some individual characters closely covaried (for example, Condylbasal L. and L. Ramus), while others displayed variation patterns that were relatively different. Character correlations are summarized in Fig. 19; we analyzed the absolute correlation values in this dendrogram, since we were interested in the degree of character

covariation rather than in whether or not the association was positive or negative. Only a couple of clearcut groups of characters can be identified, as might be expected given the cophenetic value of 0.80--some distortion in original correlations was necessary in order to summarize associations using UPGMA. Figure 19 includes a tight cluster of mostly lengths associated with the rostrum; this group is found at the top of the dendrogram (from character 1 and inclusive of character 21). A second group (4-20) encompasses most of the width measures; these two groups are joined by L. Braincase. Skull W.(at Parietals), Sep. Pterygoids, and Tooth W. combine with tooth counts to comprise another group. Widths of the internal nares and at the pterygoid sutures are loosely associated with tympanic cavity lengths. The Ht. Braincase is on the average the most divergent single character.

The presence of geographic patterns of variation was assessed for individual characters using the Mantel test and by computing matrix correlations involving interblock geographic distances and character differences. Table 9 indicates that 17 of the 36 characters exhibited what we term regional patterning in that significant associations were found between geographic distances (in nautical miles) and interlocality differences in character values. For these characters, the blocks that are geographically most distant tended to be the most different in character values, while adjacent blocks or those very close together had almost the same means for the character.

A total of 18 of the characters manifested "local patterning" as judged from the significant negative association of character differences with the reciprocals of geographic distances. Significant associations of this type result from a situation where adjacent or close blocks are very similar in character means. Because of the use of reciprocals of

geographic distances, all longer distances are represented as essentially the same; thus, the test basically evaluates whether there is local patterning--or if the very close localities are more similar than are pairs more distantly spaced. The 18 characters showing local patterning included all 17 characters with nonrandom regional patterns (Table 9). (Seldom would a character demonstrate regional but not local patterning.) Appendix 1 gives all character means for offshore S. attenuata. Generally, those characters with significant regional patterning exhibit substantial differences between northern and southern blocks. This is particularly evident in Preorbital W., Postorbital W., and Skull W.(at Zygomatic P.) (Appendices 1.09, 1.10, and 1.11), which have the most marked regional and local geographic patterns of all characters evaluated (Table 9). The animals obtained from southern blocks had substantially wider skulls than did those from the north. Note that block 0501 is more similar to the southern blocks than the northern ones, an affinity that was identified in several of the analyses involving all characters taken simultaneously.

The Mantel test, in evaluation of the presence of a pattern versus a random association, is very sensitive and identifies (through the indicating of a significant association) even weakly differentiated patterns. Thus, characters such as W. at Pterygo. Sutures (Appendix 1.27) have considerable "noise" and are evaluated as showing a very weak geographic pattern--both at the regional and local level.

For tooth counts (Appendices 1.29-1.32) of adults, only No. Teeth(Low.Rt.) showed a regional pattern, and local patterns were found in the two counts for the mandible (Table 9). When specimens of all ages were considered (Appendices 1.37-1.40), we still did not find geographic patterning for numbers of upper teeth (Table 10), but local and regional patterning were found for both characters involving the lower tooth rows.

There is a slight tendency for higher counts of lower teeth in the northern group of blocks (Appendices 1.39-1.40), although differences are very small.

Projection values of blocks onto the first two principal components (Appendices 1.41 and 1.42) were also tested for geographic patterning. As expected given the marked north to south changes in component I, it shows strong regional and local patterning (see bottom of Table 9). However, the second component does not have projections that reflect a strong geographic trend. Canonical variable 1 (Appendix 1.43) exhibits even stronger geographic trends than component I. The second canonical variable does not have regional patterns, but local patterning was demonstrated (Table 9).

Morphological-Environmental Covariation

Several analyses were conducted to assess interrelationships of morphological and environmental variables. A dendrogram summarizing the interassociations of environmental variables based on 42 blocks is given in Fig. 20. It was constructed using absolute correlations between variables instead of signed values, since our primary interest is in the closeness of variable interrelationships. The depth of the oxygen minimum layer and Sea Current(W., Winter) are closely associated, and these are joined with a tight cluster of variables characterizing sea surface temperatures and salinity. Solar insolation variables show similar distributions to that of Oxygen Minimum Layer(Thick.), and these group with the two thermocline and one sea current measures. Thermocline Depth(Ann.Var.) and Water Depth are correlated at a low level and form the most divergent group. Clearly, there are interrelationships between variables, but at the same time a wide range of variability is represented among them. No associations were 0.9 or greater and, thus, it was judged beneficial to analyze morphological

variation in relation to all 14 environmental variables.

Table 11 indicates the strength of product-moment correlations for individual comparisons of the two types of variables. In Table 12, results of Mantel tests and matrix correlations are presented, where interblock differences in five selected morphological and all environmental variables were compared. Similar findings for tooth counts from all specimens are given in Tables 13 and 14. Associations of environmental variables with principal components and canonical variables are summarized in Tables 15 and 16.

A number of significant single-character morphological-environmental associations were found (Table 11). Exact correlations, if needed, can be recomputed using the values in Appendices 1 and 4. These correlations indicate statistical relationships and not necessarily ones of biological interest. For example, all correlations with the first environmental variable, Sea Current(N.,Winter), for S. attenuata are probably statistical artifacts. For the specific set of blocks for which samples were available for this species, all of the sea current values were zero, except for block 0306. Characters, such as W. Rostrum(at 3/4 L.), which have a high correlation with Sea Current(N.,Winter) are markedly different for this particular block (see Appendix 1.08). Further investigations would be needed before any biological validity could be assigned to such associations.

The data for S. attenuata blocks on the western winter sea current (variable 2) are somewhat more varied. Six characters show a weak negative association with this environmental character. Again differences involving a single locality--in this case the western block 0501--have a substantial influence. The Sea Current(W.,Winter) is negative (-0.60 knots) for 0501, and the morphological characters with significant correlations have high

values for 0501.

The average Water Depth (variable 3) is essentially unrelated to morphological variation, with only four significant correlations. However, the fourth variable, Solar Insolation(Jan.), is the one showing the strongest correlations with morphological characters. Because of the inclination of the earth in January relative to the sun, this variable exhibits strong clinal variation from north to south (Appendix 4.04). A total of 20 of the 36 characters have significant correlation and exhibit definite north to south trends in variation. The correlations with Solar Insolation(Ann.) (variable 5) are somewhat less pronounced, although significant correlations were found for 19 of the morphological characters.

The three measures involving sea surface temperature (variables 6, 7 and 8) are correlated with a number of morphological characters, with (6) Sea Surface Temp.(Jan.) and (7) Sea Surface Temp.(July) having the strongest associations. The highest morphological-environmental correlation found (0.881) for S. attenuata was between (20) W. Temporal Fossa and Sea Surface Temp.(July). Oxygen Min. Layer(Depth) (variable 9) has a distribution (Appendix 4.09) that is different from that of any of the morphological variables. However, the thickness of the oxygen minimum layer (variable 10; Appendix 4.10) manifests a pattern that is concordant with numerous aspects of morphology; significant correlations were found for 21 of the 36 characters. Appendix 4.10 demonstrates the strong north-south trend in this environmental variable.

Fifteen of the 36 morphological measures are significantly correlated with variable 11, Surface Salinity. In addition to some east-west variation, salinity also exhibits a marked north to south trend. Only one of the morphological characters had patterns concordant with that of Thermocline Depth(Winter) (Appendix 4.12). However, the summer thermocline

values (variable 13; Appendix 4.13) had 13 morphological variables with significant affinities; most of these correlations were relatively low. The annual variation in thermocline depth (variable 14; Appendix 1.14) is not closely associated with morphological trends, in that only two weak associations were found.

Mantel tests for concordance of variation patterns of selected individual morphological and environmental variables (Table 12) gave similar results to those based on product-moment correlations (Table 11). For the length and width of the temporal fossa (morphological variables 19 and 20), as well as (10) Postorbital W., the results were nearly identical to previous findings. Only the significant, but relatively weak, correlation of W. Temporal Fossa with Thermocline Depth(Winter) is not shown to be a significant association by the Mantel test. For L. Braincase, only one concordant pattern was found using the Mantel test, while four were demonstrated through product-moment correlations; however, the additional three had only weak correlations. In a similar way, four low correlations were found for L. Rostrum(frm.Pterygoid), none of which were significant using the Mantel criterion for concordant patterning.

Correlations of environmental variables with numbers of teeth based on all specimens, rather than just adults, are summarized in Table 13. For No. Teeth(Up.Lf.), no significant correlations were demonstrated; using the smaller sample of only adult animals (Table 11), a single significant statistical association was found, which as explained above was of no biological importance. Similarly, the positive association of No. Teeth(Up.Rt.) with the first environmental measure was not found with the expanded data set (Table 13). A weak association with Solar Insolation(Ann.) (variable 5) was found. Table 13 also summarizes the seven significant correlations of No. Teeth(Low.Lf.) with environmental

variables. Six of these are the same as found earlier. Only two significant correlations of No. Teeth(Low.Rt.) are indicated in Table 11, while the analysis of all specimens gave five such associations (Table 13). Overall, the tooth counts are very uniform geographically and, thus, it is not surprising that some discrepancies would appear in results based on somewhat different data bases; not only were the numbers of specimens different, but an additional block was involved as well.

Table 14 gives the results of Mantel tests and matrix correlations of tooth counts and environmental variables that came from the expanded analysis. In contrast to what was found in other sets of comparisons, the statistical findings for Mantel tests (Table 14) did not closely correspond to those obtained by evaluating product-moment correlations (Table 13). Mantel tests identified a number of statistically significant associations of interlocality differences in environmental values with those of tooth counts. The highest concordance for each of the tooth counts was with Oxygen Minimum Layer(Thick.) (variable 10; Table 14).

Associations of environmental measures with projections onto the first two principal components and canonical variables are summarized at the end of Table 11, and summary maps for the components and variables are included in Appendices 1.41 through 1.44. Component I has high negative values to the north and positive projections in the south and for block 0501. It has significant correlations with one-half of the 14 environmental variables (Table 11), the highest being with (4) Solar Insolation(Jan.). Solar Insolation(Ann.) (variable 5) has the next highest affiliation. This component represents the general north to south variation trend in morphology for S. attenuata.

Principal component II, which had its highest correlations (negative) with tooth numbers (Table 4), had significant correlations with five of the

seven variables (Table 11) associated with the first component, in addition to having a negative correlation with Thermocline Depth(Ann.Var.) (variable 14). In this case, the closest association was -0.63 with (6) Sea Surface Temp.(Jan.). The thickness of the oxygen minimum layer (variable 10) had a similar level of correlation (-0.60) with this component.

The first canonical variable was very similar to the first principal component. The associations of this canonical variable with environmental variables were even stronger than with the component (Table 11). Eight of the 14 environmental variables showed associations with canonical variable 1. The correlation of Solar Insolation(Jan.) (variable 5) with this morphological variable was -0.93; the next highest was 0.83 with Sea Surface Temp.(July). In contrast, there were no significant relationships between environmental variables and canonical variable 2 (Table 11).

Mantel tests and matrix correlations were also used to evaluate concordance of patterning of principal component and canonical variable projections on environmental variables (Tables 15 and 16). This confirmed the finding based on product-moment correlations that component I was most similar in pattern to Solar Insolation(Jan.). The test indicates that the association of component I is slightly stronger with Sea Surface Temp.(July) and Oxygen Minimum Layer(Thick.) than with Surface Salinity (Table 15); a result similar to that obtained with correlation values (Table 11). We found 8 of the 14 environmental variables had patterns which were to some degree concordant with that of component I; these were the same variables identified in Table 11, except that in the earlier table Sea Surface Temp.(Ann.Var.) was also significantly associated with this component.

For component II, only two of the six environmental variables with high product-moment correlations (Table 11) produced significant Mantel

results (Table 15). In addition, Thermocline Depth(Summer) had significant t-values for the Mantel test.

Using Mantel tests (Table 16), canonical variable 1 was shown to have the same associations with environmental measures as indicated using product-moment correlations (Table 11). The closest correspondence was with Solar Insolation(Jan.), where a very high matrix correlation of 0.814 was obtained. Significant associations of canonical variable 1 with environmental variables (Table 16) were the same as those found for component values (Table 15), but the affinities with the canonical variable were consistently and substantially higher. Canonical variable 2 showed statistical associations with two environmental variables--Sea Current(W., Winter) and Thermocline Depth(Summer) (Table 16).

Body Length Variation

Male body lengths of S. attenuata are summarized for 39 blocks in Appendix 3.01, while those for females from 47 blocks are shown in Appendix 3.02. A total of 1,139 lengths for males and 3,783 for females were available for analysis (see block sample sizes as indicated in Appendices 3.01 and 3.02). Based on the 30 blocks where we had at least 10 males and 10 females, a two-way analysis of variance involving block and sex indicated that there is a block-sex interaction, meaning that the degree of difference between sexes in body lengths varies across localities ($F=2.51$, $P<0.001$, $df=29$). Clearly, the major source of variation is the sexual differences ($F=1,866.69$, $P<0.001$, $df=1$), although there also are significant block differences ($F=27.06$, $P<0.001$, $df=29$). On the average, males are consistently longer than the females from a given geographic locality.

Mantel tests and matrix correlations indicated no significant regional

($\underline{t}=0.51$, $\underline{r}=0.41$) or local ($\underline{t}=1.24$, $\underline{r}=-0.056$) spatial patterning in male body lengths. Similarly, for females, regional patterning was not found ($\underline{t}=1.63$, $\underline{r}=0.120$). However, the Mantel test against the reciprocals of interlocality distances showed local patterning ($\underline{t}=-2.48$, $P<0.05$; $\underline{r}=-0.103$).

Mantel tests, matrix correlations, and product-moment correlations of body length with environmental measures are presented in Table 17. In general, associations are relatively weak. However, there is a marked relationship for both males and females with Sea Current(N., Winter). Animals tend to be longer (see Appendices 3.01 and 3.02) in areas with negative values for this environmental variable (Appendix 4.01).

RESULTS FOR STENELLA LONGIROSTRIS

Seasonal Variation

Seven blocks (Fig. 7) for S. longirostris had a sufficient number of specimens to allow for an assessment of seasonal differences. A two-way analysis of variance of block (geographic location) and season (winter and summer) was completed. Two variables, involving the number of upper teeth on the left and right sides (characters 29 and 30), showed statistically significant interactions ($P < 0.01$ and $P < 0.05$, respectively) between block and season. None of the characters demonstrated significant seasonal differences. Similar results for block and season were obtained after correction to zwitter values (see below). Given the lack of any substantial seasonal shifts and with interactions being found for only 2 of 36 characters, we proceeded with our analyses and did not consider seasonal variation further.

Sexual Dimorphism

We tested for sexual dimorphism using a two-way analysis of variance, with sufficient data being available for nine blocks for comparison (Fig. 3). Three characters had significant interactions ($P < 0.05$) between sex and locality--(20) W. Temporal Fossa, (27) W. at Pterygo. Sutures, and (30) No. Teeth(Up.Rt.). In addition, the interaction term for No. Teeth(Up.Lf.) was highly significant ($P < 0.01$). We found statistically significant sexual dimorphism in 13 of the 36 morphological characters (Table 18). For several characters involving the length of the rostrum, female means were slightly greater (Table 18), although not significantly so. Males were larger in most other characters, with a number of widths exhibiting statistically significant differences. Since sexual dimorphism was demonstrated for over one-third of the characters, and we judged that

additional differences of significance would be found with larger sample sizes, all character values for individual dolphins were corrected to zwitter values using the terms listed in Table 18. While re-analysis of the zwitter values did not change the significant interactions, it did eliminate all of the significant sexual differences. Block means of zwitter values for S. longirostris are included for each character in Appendix 2.

Geographic Variation

In order to summarize general variation patterns, we conducted a principal component analysis. Character loadings on the first four components are presented in Table 19. The first component explained 55.3% of the total character variance, the second 14.8%, the third 7.3%, and the fourth 5.3% (cumulative total of 82.7%). Projections of blocks onto the first two components are shown in Fig. 21. Principal component I has relatively high correlations (Table 19) with all except a number of tooth characters and (23) Sep. Pterygoids. Localities to the right of the diagram (Fig. 21) are southern ones where animals are, in general, larger in size, while the smaller S. longirostris are characteristic of northern sites that have negative projections on component I.

The second principal component separates the coastal block 0508 and to some extent block 0804 from the others (Fig. 21). This component has relatively high negative correlations with tooth characters (Table 19). Blocks toward the bottom of Fig. 21 tend to have slightly higher numbers of teeth and longer tooththrows.

Component III is plotted against component I in Fig. 22. It emphasizes differences of blocks 0307, 0404, and 0607 at one extreme and localities 0501 and 0804 (with positive projection values) at the other. Specimens

from the latter two blocks tended to have larger tympanic cavities (see loadings for characters 25 and 26; Table 19), while those of individuals from blocks with negative projections had smaller cavities.

The fourth component has its highest association (a negative one) with (15) Max. W. Premax. (Table 19). The southwestern blocks 0403 and 0404 with positive projections on this axis (Fig. 23) are relatively small for this character.

Figure 24 is a dendrogram resulting from a UPGMA cluster analysis of the 20 blocks for S. longirostris. Some distortion of the original average distances in the multidimensional character space was needed to summarize interblock associations with a phenogram. Three clusters are evident. The first (blocks 0109 through 0404 in Fig. 24) includes southern and western localities. The second contains only a single block (0508), and the third has the remaining blocks. Those in the third cluster are situated to the north and east of the other blocks, with the exception of block 0403--it is a southwestern locality and in the diagram is somewhat separated along with 0804 from others in this group.

Clustering using the adaptive hierarchical clustering scheme (Fig. 25) gave a result that was similar to that summarized in Fig. 24, although some differences are evident. Block 0508 was the most divergent of the localities, being placed in its own cluster at the bottom of Fig. 25. The group at the top of the dendrogram (Blocks 0109-0307) was the same as the one formed using UPGMA, except that block 0404 was not included. A second cluster (0403-0606) was also similar to one found using UPGMA; within this group the distinctness of four blocks (0507, 0604, 0605, 0606) with respect to the rest of the localities is emphasized in Fig. 25. The far northeastern block (0804) is shown as being rather different from others in this group.

A generalized skyline diagram (Fig. 26) resulting from function-point clustering based on the 36 characters demonstrates an initial subdivision of northern and southern blocks. At the w value of 4.25, six southern blocks (indicated with ones) are grouped, with the rest being in a second cluster (designated with twos). At the next level (3.93), the same two groups are found, with two exceptions: (1) block 0508 is placed in a cluster by itself; and (2) block 0501 is switched to the cluster of southern blocks. More detailed subdivisions are also presented in Fig. 26 for the higher w values.

A similar analysis (Fig. 27) was conducted using only the five characters—(10) Postorbital W., (8) W. Rostrum(at 3/4 L.), (33) L. Low. Toothrow, (24) W. Internal Nares, (27) W. at Pterygo. Sutures—which were, in combination, the best for discriminating between blocks (based on results of multiple discriminate analysis reported below). The southern blocks are placed together with 0508 (which eventually is put in a cluster of its own), and the rest of the blocks are placed in another section. Block 0501 is placed in a group by itself and then with 0505 (w value of 0.93). At 0.85, it is joined with several other blocks.

For a canonical variates analysis, using as initial data the information on the 36 measurements, we set the F-value to enter at 1.5. The nine morphological characters listed in Table 20 were incorporated into the canonical variables. A two-dimensional plot of the 20 blocks on the first two canonical variables is included as Fig. 28. The eigenvalue for canonical variable 1 is 3.376 and that for the second is 0.469, with the two summarizing 77.6% of the total dispersion. These nine characters in combination, relative to the within group variance, show the greatest among-group variability. We selected the initial five that were entered (see Table 20) for more detailed comparisons with environmental variables.

The plot of the two canonical variables (Fig. 28) shows a clear separation of the southern (left) and northern localities; block 0501 is placed in a position somewhat intermediate between the two main groups. The second axis separates 0508 from the other northern localities and to a lesser extent 0404 from the other southern blocks.

Figure 29 is a dendrogram that depicts the associations among characters as they vary over the 20 blocks for S. longirostris. Most characters had positive correlations. The negative signs associated with a few of the correlations were deleted since we wanted to determine the degree of covariation irrespective of whether it was positive or negative. The (23) Sep. Pterygoids is the most divergent character, and the correlation of tooth counts with other characters is also low. The cluster at the top of the diagram (characters 1 through 33) includes length measures, and these are correlated with three width measures involving the premaxillaries (15, 17, 18). Three rostrum widths are closely associated with (19) L. Temporal Fossa, and this group is affiliated with a variety of length, width, and height characters, most of which measure aspects of the main part of the skull. Several other clusters involving one or two characters are included in the dendrogram (see Fig. 29).

Individual characters were evaluated with respect to geographic patterning using Mantel tests as well as matrix correlations of interblock geographic distances (and alternately of the reciprocals of these distances) and character differences between localities. Of the 36 characters, 72.2% (26) show statistically significant regional patterning; geographic distance (in nautical miles) and interblock character differences are associated (Table 21). For measures showing significant t-values the greatest character differences tend to be between blocks that are furthest away, while close localities are relatively similar.

Local patterning, as indicated by a significant negative association of distance reciprocals and character differences, was found in 77.8% (28) of the characters (Table 21). One character, (8) W. Rostrum(at 3/4 L.), had regional but not local patterning while two, (26) L. Rt. Tympanic Cavity and (28) L. Up. Toothrow, exhibited only local associations.

We also evaluated patterning in tooth count data based on all specimens (242) of S. longirostris (see block means in Appendices 2.37-2.40). Table 22 included t-values from Mantel tests and matrix correlations of interlocality differences in these tooth counts with geographic distances and the reciprocals of these values. No geographic patterning was found in any of the four characters, whether at the local or regional level.

The principal component projections were also assessed in terms of the degree of geographic patterning. Block projections are summarized in Appendices 2.41 to 2.44. As indicated at the bottom of Table 21, component I has strong regional and local patterning. However, the other components are essentially random with respect to the association of interblock differences and geographic distances. As was indicated earlier, these last three components summarize differences of one or a few blocks from the rest of the localities and, thus, the lack of distinct geographic patterning is not unexpected.

Projections of blocks onto canonical variables 1 and 2 are given in Appendices 2.45 and 2.46. As with principal component I, the first canonical variable exhibits strong regional and local patterning (Table 21). Relatively high projection values are found in most northern localities, while southern ones have negative projections (Appendix 2.46). Canonical variable 2 is not geographically patterned (Table 21).

Morphological-Environmental Covariation

In Table 23, the presence of statistically significant product-moment correlations of morphological and environmental variables is indicated. We also assessed covariation of the five discriminating characters and environmental measures using Mantel tests and matrix correlations (Table 24), while Table 25 provides this information for tooth counts based on all specimens. Table 26 shows the results of the same type of analysis for the first four principal components; similar findings for the first two canonical variables are summarized in Table 27.

Several of the environmental measures showed no association with trends in morphological characters while others exhibited close covariation (Table 23). The values used in computing these correlations are given in Appendices 2 and 4. The first environmental variable, Sea Current(N.,Winter) (Appendix 4.01), has only weak correlations with 3 of the 36 morphological measures. For these characters, such as W. Internal Nares (see Appendix 2.24), the values for blocks 0109, 0209, and 0508 tend to be relatively high and 0804 low, thus creating a slight association with this sea current variable. The other character summarizing sea current information (Appendix 4.02) also has a geographic pattern that in general is not like those for morphological characters. Only (21) Orbital W. has a significant correlation, and this association is relatively weak.

Water Depth (variable 3) is positively correlated with six morphological measures, two (20, W. Temporal Fossa and, 25, L. Lf. Tympanic Cavity) of which have highly significant values ($P < 0.01$). For these six variables, relatively large measurements were recorded for 0501 and 0109, which have relatively deep waters, while more shallow localities like 0804 had animals that were smaller for these characters.

The fourth environmental measure, Solar Insolation(Jan.) (Appendix

4.04), is one of the most highly associated with morphological variation. Solar insolation at this time of the year exhibits a strong trend from high values in the southern part of the range of S. longirostris to low values in northern areas. It has positive correlations with 69% (25) of the 36 variables. The associations with three width measures--(9) Preorbital W., (10) Postorbital W., and (11) Skull W.(at Zygomatic P.)--were particularly high (0.818, 0.838, and 0.825, respectively).

Annual solar insolation (see Appendix 4.05) exhibits a pattern involving high values at the earth's equator and a decreasing function as one proceeds toward either pole. Only six of the morphological variables have significant correlations with this environmental factor, and all of these correlations are relatively weak.

The sixth environmental variable, Sea Surface Temp.(Jan.) (Appendix 4.06), has several comparatively strong correlations with morphological characters (Table 23), with 11 characters demonstrating negative associations. However, for S. longirostris, it is (7) Sea Surface Temp.(July) (Appendix 4.07) that exhibits the environmental pattern most like those found for morphological measures. As indicated in Table 23, over 77% (28 of 36) of the skull characters evaluated were negatively correlated with the sea surface temperature in July. The three highest morphological-environmental correlations found in the study of S. longirostris were on this variable. The association with (9) Preorbital W. was -0.895, (10) Postorbital W. was -0.886, and (11) Skull W.(at Zygomatic P.) was -0.887. Other correlations with this factor were also relatively high--a -0.818 with (14) L. Braincase and a -0.837 with (15) Max. W. Premax.

We also found that the annual variation in sea surface temperature (variable 8) is similar in geographic pattern to a number of morphological

characters (Table 23). A total of 23 characters had significant positive correlations; for these measures, the animals tended to be larger where there was greater variation in temperature.

Only a single, weak negative correlation of a morphological variable with (9) Oxygen Minimum Layer(Depth) was found. However, the thickness of the oxygen minimum layer (variable 10) was negatively associated with 14 of the 36 morphological characters. This variable (see Appendix 4.10) has its highest values in the area of the northern S. longirostris samples, while thicknesses of only about one-half as great are characteristic of the southern blocks of our study area.

There was little association between morphological variation and that found in (12) Thermocline Depth(Winter) or (14) Thermocline Depth(Ann. Var.). The former had only one weak negative correlation with a morphological character, while no significant associations were recorded for the latter. The 13th environmental measure, Thermocline Depth(Summer) (Appendix 4.13), also showed few significant correlations--only four morphological characters had positive associations. However, those with the tympanic cavity lengths (variables 25 and 26) were relatively high.

In Table 24, we have summarized Mantel tests and matrix correlations for concordance of patterns of morphological variation for selected characters and environmental variables. Findings using these methods are virtually identical to our results based on product-moment correlations. For Postorbital W., we obtained six significant associations using the Mantel test (Table 24); these are the same variables with significant product-moment correlations. The closest concordance in patterning is of Postorbital W. with Sea Surface Temp.(July); the t-value is 9.24 and the matrix correlation is 0.736.

Based on Mantel tests the second variable included, W. Rostrum(at 3/4

L.), exhibited a geographic distribution of mean values that was independent statistically from that of any environmental measure used. The same conclusion was reached on the basis of product-moment correlations (Table 23). Two significant t-values were obtained for the L. Low. Tooththrow, one with Sea Surface Temp.(Ann.Var.) and the other with Surface Salinity (Table 24). Correlations of the 20 locality values also produced two significant tests (Table 23); these were with the former variable and with (7) Sea Surface Temp.(July). The result for Surface Salinity based on interblock differences is clearly different from what was found by analyzing the block values themselves.

In Table 24, a total of seven significant associations are reported for W. Internal Nares. We also found seven significant product-moment correlations (Table 23), with six of the seven being with the same environmental variables. The correspondence is also close for W. at Pterygo. Sutures. For this character, five of the six environmental measures with significant correlations (Table 23) also had significant t-values for the Mantel tests (Table 24). Since the two ways of evaluating pattern association are sensitive to different types of pattern differences, such close concordance in results does not necessarily follow from working with the same initial data sets.

For S. longirostris, the tooth counts (variables 29-32) for adult specimens showed no associations with environmental variables (Table 23). Even with the expanded data for 242 specimens from 22 blocks (Appendices 2.37-2.40), there was little evidence of covariation of such counts with environmental variables. The only two statistically significant ($P < 0.05$) correlations involving the four tooth variables with the 14 environmental measures were of numbers of upper teeth with Solar Insolation(Ann.). Both were negative (-0.46 for left side and -0.48 for right side) and relatively

weak.

Mantel t-values and matrix correlations (Table 25) indicated a few additional significant associations of tooth counts with environmental variables for this species. In addition to significant associations of upper tooth counts with Solar Insolation(Ann.), these morphological variables also covary with Water Depth and Sea Current(N.,Winter). The only statistically significant Mantel value for lower tooth counts was of No. Teeth(Low.Lf.) with Water Depth.

Projections onto the first four principal components, which are summarized in Appendices 2.41 through 2.44, were also investigated to determine the association of their distribution patterns with those of environmental variables. Product-moment correlations of components with environmental measures are represented in Table 23. The first component has high correlations with Solar Insolation(Jan.) (0.761) and Sea Surface Temp.(July) (-0.801), as well as lower correlations with two other environmental variables. The remaining three principal components show very little association with environmental measures. Component II has a weak correlation with only one of these variables, while the other two components each have significant but low associations with two environmental characters.

The first canonical variable (Appendix 2.45), for which projections have signs opposite those of principal component I (Appendix 2.41), has relatively high correlations with environmental variables (Table 23). Eight significant correlations were found, the highest of which are 0.89 with Sea Surface Temp.(July) (variable 7) and -0.84 with Solar Insolation(Jan.) (variable 4). The second canonical variable (Appendix 2.46) behaves independently with respect to any of the environmental measures, with no significant associations being found (Table 23).

Table 26 presents findings resulting from Mantel tests and matrix correlations for principal component values. We found six significant associations for component I, five of which were identified using product-moment correlations (Table 23). The sixth significant correlation, involving Sea Current(W.,Winter), was highly unusual in that a negative matrix correlation was found (i.e., when interblock differences in component scores were large, sea current differences tended to be small); it is highly doubtful that such a correlation has any biological meaning. One negative association of component I with Oxygen Minimum Layer(Thick.) that was significant on the basis of correlations was not identified as such using the Mantel test.

An association of component II with Water Depth was also found using the Mantel test. Also, a weak correlation with Sea Current(N.,Winter) was demonstrated (Table 26). These tests did not find any statistical associations involving principal component III and only two relatively weak relationships were identified for the fourth component (Table 26).

The Mantel tests and matrix correlations involving canonical variables and environmental measures are given in Table 27. The six strongest associations for canonical variable 1 already identified with product-moment correlations (Table 23) are also demonstrated in the Mantel results (Table 27). A strong concordance is shown between variable 1 and Sea Surface Temp.(July); the relationships with Solar Insolation(Jan.) and Surface Salinity are also particularly marked. Only a single statistical association was identified for the second canonical variable, that being with Water Depth (Table 27).

Body Length Variation

For S. longirostris, body lengths were obtained for 1,003 males from 35 blocks and 1,352 females from 37 blocks. Block means and individual

sample sizes are presented in Appendices 3.03 and 3.04. For 25 blocks, at least 10 males and 10 females were available, and a two-way analysis of variance was employed to evaluate block and sex influences. No significant interaction ($F=1.35$, $P>0.05$, $df=24$) for these two factors was found. Very substantial sexual differences are evident ($F=213.16$, $P<0.001$, $df=1$), and the block variability is also very highly significant ($F=14.79$, $P<0.001$, $df=24$). The males are larger than females (see Appendices 3.03 and 3.04).

Body lengths for males showed regional patterning ($t=2.23$, $P<0.05$; $r=0.189$) and local patterning ($t=3.44$, $P<0.001$; $r=-0.186$) based on findings of Mantel tests and matrix correlations. For females, no regional patterning was demonstrated ($t=0.70$, $P>0.05$; $r=0.043$). However, local patterning is evident ($t=-2.65$, $P<0.01$; $r=-0.114$).

Table 28 summarizes associations of body lengths for S. longirostris with the 14 environmental measures. The Mantel tests, matrix correlations, and product-moment correlations show relatively strong concordances of variation patterns of lengths with those of a number of environmental patterns. For males, Mantel t -values and product-moment correlations were statistically significant for one-half of the tests. Six of the seven significant associations were identified by both tests, while each test also gave one additional significant result (see Table 28). The most marked covariation of male lengths was with values for sea surface temperature in July. For females, Mantel tests found six significant associations with environmental variables, while product-moment correlations identified these plus one additional significant association (Table 28). The variation pattern of female lengths showed its greatest similarity with that exhibited by the thickness of the oxygen minimum layer, a variable that has little or no association with variation in male lengths.

RESULTS OF INTERSPECIFIC COMPARISONS

Sexual Dimorphism

A greater number of the morphological characters were shown statistically to be sexually dimorphic for S. attenuata (23 of 36) than for S. longirostris (13 of 36). Sample sizes for the former were substantially larger and, thus, the disparity might at least in part be explained by the relation of sample size to statistical significance levels (but see below). Basically, the same trends in sexual dimorphism are found in the two species. For 25 of the characters, the males of both species were larger than the females, while in 7 the females were the larger (Tables 3 and 18). For two characters, one of the species had no difference between the sexes. Only in two characters was there a difference in the sign of deviation, with the females being bigger in S. longirostris and smaller in S. attenuata. However, differences in both cases were very small.

In evaluating the extent of sexual dimorphism in the two species, we tabulated from Tables 3 and 18 the number of cases where the absolute sex differences were greater in one than the other species. For the 25 characters where for both species the males were larger, we found that in 19 cases sexual dimorphism was more pronounced in S. attenuata, while only 7 times was the deviation greater in S. longirostris. In six of the seven characters where females were larger in both species, the disparity was greater in S. attenuata than in S. longirostris.

Since S. attenuata is somewhat larger for some characters than S. longirostris, the actual intersexual differences in the former might be expected to be greater. Thus, we also compared the percentage differences which are summarized in Tables 3 and 18 for each of the characters. The findings for percentage differences were identical to those based on

absolute differences. Thus, it is clear that the degree of sexual dimorphism in S. attenuata is greater than in S. longirostris.

Geographic Variation

The predominant trends in the data sets for each of the species were summarized with principal components and canonical variables. Information is available for 13 blocks from which both offshore S. attenuata and S. longirostris were sampled (Fig. 30). These blocks are representative of the total geographic range investigated in our study. In order to compare general patterns of variation in the two species, we calculated product-moment correlations, Mantel tests, and matrix correlations for the principal component projections of these 13 blocks. The two components for S. attenuata were evaluated against the four that were analyzed for S. longirostris (for summary information on the components, see Fig. 15 and Table 7 for offshore S. attenuata; Figs. 21-23 and Table 19 for S. longirostris). As indicated in Table 29, there is a strong correspondence between the first components for the two species, but for the other components, the only association found was a weak one between component II of S. attenuata and IV of S. longirostris.

A similar interspecific comparison was made of projections of the 13 blocks onto the first two canonical variables (Table 30). The first canonical variable for S. attenuata and that for S. longirostris are very highly correlated and are judged to represent highly concordant geographic patterns for the two species. While the block projections on the first canonical variables for the two species were very similar, the actual characters that make up or define the variables are not the same (see Tables 8 and 20). Of the seven characters entered for S. attenuata and the nine for S. longirostris, only three--(10) Postorbital W., (14) L.

Braincase, and (18) W. Rt. Premax.(md.Nares)--are present in both character sets.

In our analyses, average distances based on morphological characters were computed between each pair of localities. These distances are summarized in dendrograms for S. attenuata (Fig. 9) and S. longirostris (Fig. 24). To evaluate the extent of similarity in geographic patterns, the original distance matrices for each species were modified such that only distances among the 13 localities common to both species were included. These matrices were then compared using the Mantel test and computing the matrix correlation. The t-value for the Mantel test was 3.03 ($P < 0.01$) suggesting that there was a considerable degree of similarity between the overall morphological patterns of S. attenuata and S. longirostris. The matrix correlation value is 0.477.

For the 13 blocks, we also made interspecific comparisons of the individual morphological characters. Table 31 includes results of Mantel tests, matrix correlations, and product-moment correlations. Twelve of the 36 t-values for Mantel tests of the interlocality differences for the two species were significant, while 13 of the 36 product-moment correlations indicated statistical association for individual characters between the two species. Nine of the 10 characters with positive correlations were width measures. Furthermore, the tenth is (22) L. Antorbital P., which is essentially a width measure as well (see Fig. 5). The two characters involving the temporal fossa (variables 19 and 20) exhibited negative correlations. For S. attenuata, the (19) L. Temporal Fossa is greater in the northern localities, while in S. longirostris the shorter fossae are found in this geographic area (Appendices 1.19 and 2.19). A similar trend is shown for the widths in Appendices 1.20 and 2.20.

Morphological-Environmental Covariation

In both S. attenuata and S. longirostris, there were marked correspondences of morphological measures with environmental variables. Each had a number of morphological-environmental associations that were relatively high (see for example Tables 11 and 23). In general, for S. attenuata the greatest degree of environmental-morphological correspondence was with (4) Solar Insolation(Jan.). With S. longirostris, the negative correlations involving (7) Sea Surface Temp.(July) were the most pronounced. The differences between the two species were relatively minor in nature; the overall finding is one of similar relationships of within-species variation in skull morphology to environmental variation.

Body Length Variation

Substantial numbers of lengths (i.e., 10 or more) of males were available for both species in 21 blocks. Product-moment correlation indicates that there is no association between length values for males of the two species ($\underline{r}=-0.298$, $P>0.05$). The Mantel test and a matrix correlation provide the same result ($\underline{t}=1.20$; $P>0.05$; $\underline{r}=0.164$). For females, 35 blocks had 10 or more specimens for both S. attenuata and S. longirostris. The correlation was highly significant and negative (-0.475 , $P<0.01$). The Mantel test and matrix correlation also showed a significant association ($\underline{t}=2.08$, $P<0.05$; $\underline{r}=0.158$). The longest females of S. attenuata are found in the northeastern blocks, with smaller individuals being typical of western and southern areas (Appendix 3.02). In contrast, female S. longirostris tend to be smaller in the northeastern localities and larger in blocks to the west and south (Appendix 3.04).

DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

In 1889, True indicated that the absence of adequate specimen samples made the task of the taxonomist involved in evaluating the species in the genus Stenella a very difficult and disheartening one. Perrin (1975b) found that he had available considerably more material for a monographic treatment of S. attenuata and S. longirostris from the eastern tropical Pacific. He made significant advances with respect to our understanding of morphological variation of Stenella. However, his work was also hindered by the paucity of material from some parts of the range. We have been provided with many additional specimens and, while on the whole our results are strongly supportive of those obtained by Perrin (1975b), we also have been able to extend his analyses in a number of significant ways.

Our findings also supplement and interrelate with the results of recent investigations of: (1) the relationship of environmental features to dolphin distributions (Au, Perryman, and Perrin 1979; Perrin, Coe, and Zweifel 1976); (2) distributions and movements (Perrin 1975a; Perrin, Evans, and Holt 1979; Perrin and Henderson 1979; U.S. Dep. Commerce 1977); (3) morphology and taxonomy (Perrin 1975a; Perrin, Coe, and Zweifel 1976; Perrin, Holts, and Miller 1977; Perrin, Sloan, and Henderson 1979); and (4) growth and differentiation (Perrin, Coe, and Zweifel 1976; Perrin and Henderson 1979; Perrin, Holts, and Miller 1977). Below we have discussed our findings in relation to those of other investigators, first for S. attenuata and then for S. longirostris.

Stenella attenuata

Seasonal Variation

The extent of seasonal and other movements of S. attenuata could

influence our data and analyses, as well as determine the adequacy of our method of grouping specimens for study (i.e., in 5° blocks and for all seasons). Norris (1967) indicated that some dolphins appear to be quite sedentary, although others may be relatively mobile. Evans (1971, 1974) has shown that common dolphins (Delphinus delphis) move up to 65 n.mi. in a day. Perrin (1975a) and Perrin, Evans, and Holts (1979) reported on extensive tagging operations of small cetaceans in the eastern tropical Pacific from 1969 through 1976. A total of 2,996 S. attenuata were marked, with recoveries of 97 tagged animals. These recaptures ranged from 2 h to 4 years after marking, and movements ranged from 7 to 582 n.mi. Investigators indicated that short-term movements involved about 30 to 50 n.mi. per day. As is indicated in maps included in Perrin, Evans, and Holts (1979), the longest movements recorded span about two of our 5° blocks. There is a suggestion of a yearly cycle or movement pattern in S. attenuata, although additional information will be needed determine whether such movements are typical of the species throughout its range.

In our morphological comparisons of intrablock seasonal differences for S. attenuata, we did not find substantial and uniform differences between winter and summer block values for individual characters. However, 10 of the 36 characters exhibited interactive effects, meaning that the influence of season is different for different blocks. Seasonal migrations of S. attenuata would be much more likely to produce such statistical interaction than to result in a consistent difference in the mean of a character in all blocks. This is because seasonal movements would probably raise the character mean for some blocks, lower it for others, and have no effect on others, particularly since such migrations are not likely to be strictly in one compass direction throughout the range of the species.

Our findings of very significant character patterning, as well as

close concordance of a number of morphological and environmental characters, indicate that the considering of all specimens, irrespective of season, has not unduly influenced our overall conclusions concerning geographic variation in S. attenuata. However, the availability of larger samples from different seasons for all or most blocks might enable future investigators to provide more precise information on seasonal shifts in populations or subpopulations of S. attenuata, particularly if seasonal movements are similar from year to year. Typically, geographic variation studies of migratory terrestrial vertebrates are most often done on specimens from a given seasonal period. Eventually, with the obtaining of additional material, this approach may be possible for S. attenuata. If this species proves to be cyclic in its seasonal movements, the focussing of morphological studies on seasonally-partitioned data sets would be desirable.

Sexual Dimorphism

Prior to Perrin's (1975b) study, sexual dimorphism in the skeleton had not been convincingly demonstrated for a delphinid, although Fischer (1881) indicated that such may have been the case in Delphinus delphis. Perrin (1975b) was able to detect dimorphism only in the braincase, feeding apparatus and postcranial skeleton. In general he found adult females to be smaller than males, and the females had a longer snout. Using a series of 40 characters involving the skulls and absolute measurements, he obtained only a single significant difference between sexes--in (1) Condylbasal L. When he used relative measures, an additional six characters exhibited sex differences in skull dimension.

The basic trends suggested by Perrin (1975b) were confirmed by our analyses, although Condylbasal L. was not one of the characters that we

found to be significantly different; our results suggest that the rostrum is elongated in females relative to males, but that overall skull length is about the same. The finding that 64% of our measurements exhibited sexual dimorphism significantly extends information on this phenomenon for S. attenuata. The increased numbers of specimens now available has enabled us to determine more precisely the extent to which males and females differ. Furthermore, by being able to analyze sexual dimorphism within blocks, we have been able to factor out influences of geographic variation. Much of the sexual dimorphism found was relatively minor, with differences involving only a few percentage points or less. However, correcting for this factor, as we have done, allows for a more sophisticated analysis of geographic differences, particularly for characters where the differences between distant localities were also relatively small. We recommend that in future studies of skull morphology that a similar correction be made or that the sexes be analyzed separately. To do the latter would require considerably larger collections, even for some blocks that we were able to analyze using our procedures. Attempts should be made to obtain skeletal material for both sexes from throughout the range of S. attenuata.

Geographic Variation

Perrin (1975a,b) demonstrated pronounced geographic variation in S. attenuata, a topic which had not been approached earlier because of the paucity of material. Samples now available (622 adult specimens) are considerably larger than were available to him (i.e., 132 specimens from the eastern tropical Pacific) and, thus, further definition and analysis of geographic patterning is possible.

In his studies, Perrin (1975a,b) identified and described a coastal form which he called S. attenuata graffmani. It corresponds to our onshore

group, which is shown to be very distinct from the offshore populations in all of our analyses. As Perrin (1975b) found, the onshore skulls are substantially larger than those from offshore areas. He suggested that onshore and offshore series are not as divergent in dimensions of the braincase as they are in *Condylobasal L.* However, our results (see F-values in Table 5) suggest that, while in absolute terms this is the case, when one examines the differences relative to within-group variability the braincase differences are about the same as those for skull length.

In the feeding apparatus there are significant differences, with the offshore form having a more attenuate rostrum. Perrin noted that tooth counts were the same, and our results tend to support his general conclusion. Just 3 characters of the 36 analyzed exhibited only minor differences, these being counts of teeth (Table 5). Tooth counts were very similar, although our sample sizes were sufficient to demonstrate statistical significance involving less than one tooth differences per tooth row. Perrin's analyses indicated differences in tooth width between the groups, and our investigations show that it is in this character of the skull where the most dramatic difference is found. While some overlap exists, this single character will separate the majority of specimens. Tooth W. is the first character entered into the canonical variable (Table 6) and in combination with others can result in virtually complete separation between onshore and offshore specimens. In addition to the characters mentioned above, Perrin and we have found differences in all other types of characters as well.

Our overall findings basically agree with those of Perrin (1975a,b), although they do not necessarily support the idea that the greatest differences are exhibited by characters associated with the feeding

apparatus. Certainly, as Perrin indicated, the differences between onshore and offshore forms is not one of size alone but also of proportions. Perrin (1975b) has suggested that the differences reflect differences in feeding ecology.

The canonical variable and classification functions provided in Table 5 can be used, after correction for sex, to identify skulls as being from onshore or offshore populations. Additional material is needed to investigate geographic variation within the onshore area. Results indicate marked differences in some characters between the northern and the three southern blocks of the onshore S. attenuata. More specimens should be obtained from intermediate localities, as well as from those even further south, in order to allow more detailed evaluation of subdivision within S. attenuata graffmani.

Perrin (1975b) has suggested that a cline may exist with respect to character variation in the area of contact or overlap between the onshore and offshore forms. This question cannot be fully addressed without additional specimens; the availability of more specimens would allow investigators to evaluate in more detail questions relating to the specific status of the onshore animals. Perrin's (1975b) analyses hinted that differences between the onshore and offshore series are most pronounced at the northern and southern extremes of the range, where there is apparent separation of the forms; he hypothesized that this may imply onshore-offshore gene flow in the more central localities.

Our analysis, which involved seven specimens that we treated as "unknown", identified four with placements intermediate between typical onshore and offshore phenotypes (see Fig. 14). Two of these, 0705-101 and 0804-54, had relatively high probabilities of being correctly identified as being part of the onshore group. However, specimens 0705-102 and 0705-103

had discriminant scores that situated them almost exactly on the division point on the discriminant scale. Specimen 0804-54 had not been included in previous analyses (Museum code SWFC DJT045). However, specimen 0705-101 had been identified by Perrin (1975b) as an onshore animal (USNM 395926), as had 0705-102 and 0705-103 (USNM 395927 and 395928) which are from the same locality (see Fig. 4). More specimens from the zone of contact or overlap of the two forms, particularly taken at localities from 10 to 20 N, will be critical if morphological information is to be used in addressing with more precision questions concerning the affinities of these two forms.

Of the four specimens that were sole representatives of geographic blocks with shoreline, only one (from 0706; NMNH 395929) has been reported on previously. Perrin (1975b) included it as an onshore animal. Our measurements and calculations strongly suggest that it has characteristics typical of the offshore form, and we recommend that in the future this specimen be treated as an offshore representative.

In Perrin's works of 1975(a,b), he also found that geographic variation was present in offshore areas, with changes being found from east to west. At that time, virtually nothing was known about more southerly populations. Specimens and observations first became available for S. attenuata from south of the equator in 1975, and subsequently Perrin, Sloan and Henderson (1979) have described some of the differences between the southern and other populations of this species. They had 17 S. attenuata skulls available for analysis from these southern areas; we have been able to make use of additional material that has been collected. Perrin, Sloan, and Henderson (1979) found the southern specimens to be more like those from the vicinity of Hawaii than those directly north, across the equator. They suggested that in the single feature for which the Hawaiian S. attenuata were smaller than offshore animals--the temporal fossa (length

and width)--the southern group exhibited similar variation.

Our principal component analysis (see Table 7 and Fig. 15) indicates that in general the skulls are more robust in the southern versus the other offshore S. attenuata. However, as found by Perrin, Sloan, and Henderson (1979), the temporal fossa did not show this trend; the measurements for its length and width were considerably smaller in the southern populations (see Appendices 1.19 and 1.20).

While not shown particularly by these two characters, the overall data set reflects similarity between the southern blocks and block 0501, which is the most westerly offshore block for which material is now available (see for example Fig. 18). Additional samples are needed from the western portion of the range of S. attenuata in the eastern tropical Pacific in order to confirm such a relationship if it exists and to provide details concerning the geographic variation patterns in terms of how southern, offshore, and far offshore samples interconnect. In particular, more samples are needed from west of 115° longitude, as well as from 0° to 5° N latitude. Other records (see Perrin, Sloan, and Henderson 1979) suggest that there may be a dearth of dolphins from the 0° to 5° N latitudes, which strongly implies a significant degree of isolation between northern and southern forms. We judge that current information fully warrants the recognition of the southern S. attenuata as a distinct stock. Additional specimen material should enable future investigators to provide more detail as to the relationship of animals found west of 120° to the other dolphin stocks.

Morphological-Environmental Covariation

As summarized by Au, Perryman and Perrin (1979), the eastern tropical Pacific Ocean is wedged between the two major circulatory gyres present to

the north and south in the eastern Pacific Ocean. It is characterized by relatively low salinity, a two-layered structure, and a sharp thermocline. Bounded by currents to the north and south, this region has an easterly-flowing equatorial counter current at 3° to 10° N. Often there is a massive oxygen minimum layer, and zonal currents are strongly seasonal. Overall, the eastern tropical Pacific Ocean is highly productive, and Wyrteki (1967) concluded that upward transport of water and nutrients occurs throughout the region. While a number of the characteristics listed above apply uniformly to the entire region, there also is considerable spatial variation with respect to environmental parameters, as indicated by the environmental measures employed in our analyses (Appendix 4). Thus, the opportunity exists for the influence of environmental conditions on morphological characteristics in such a way as to produce geographic variation in these characteristics. While correlational studies, such as the one we have undertaken, cannot in most cases prove the existence of any causal relationships, they are an important initial step that can lead to an increased understanding of the relationships of morphological and environmental variation.

Very few analyses are available of associations between morphological and environmental variation in marine mammals. Rather, most such studies involving environmental variation have been done with respect to abundances and limits of distributions. For example, Volkov and Moroz (1977) investigated distributions of whales in the eastern tropical Pacific Ocean in relation to hydrological and hydrobiological conditions. They found a drop in abundances of whales between 3° and 7° N. Perrin, Coe, and Zweifel (1976), as well as Au, Perryman and Perrin (1979), have evaluated dolphin distribution patterns relative to environmental features of the eastern tropical Pacific Ocean. Brodie (1975, 1977) has investigated aspects of

whale energetics and intraspecific size variation in these animals. However, because of lack of extensive blubber in dolphins, a number of assumptions and considerations of importance for whales would be inappropriate if applied to dolphins.

The 24° C isotherm encloses more than 98% of the S. attenuata and S. longirostris sightings in the eastern tropical Pacific Ocean. Many of the dolphins are located in zones of rapid change in surface temperatures, where temperate or seasonally-cooled, subtropical waters transcend into tropical waters (Au, Perryman and Perrin 1979). With the enhanced feeding opportunities, dolphin abundances seem to increase in areas of convergences and fronts. Apparently, there is an absence of widespread movement from south to north of the equator during the southern winter. Perrin, Coe and Zweifel (1976) showed an association between S. attenuata abundances and the thickness of the oxygen minimum layer in the Eastern Tropical Pacific, an environmental variable we also analyzed with reference to morphological variation in this species.

With respect to the relationship of morphology to environmental variation, the most striking association found in our investigation of offshore S. attenuata was with Solar Insolation(Jan.). The strong north-to-south trend in variation of this environmental variable corresponds with the marked differences between northern and southern S. attenuata. However, there is evidence of such trends even within these geographic regions. Temperature variables also exhibited strong associations, with the highest single character correlations being found between W. Temporal Fossa and Sea Surface Temp.(July). As indicated above, there is a relationship of the thickness of the oxygen minimum layer and S. attenuata abundance. This environmental variable also covaries with many (21 of 36) of the morphological characteristics we studied.

Overall, there were notable associations between morphological and environmental variables. In order to further evaluate such trends, more samples are needed particularly from locations further to the west. Such a geographic broadening of representation might enable investigators to separate, at least in part, environmental-morphological correspondences that may represent causal relationships from what could be primarily north-south trends maintained largely as a result of isolation by distance. Our present lack of ability to conclusively differentiate between these possibilities does not, however, detract from the conclusion that several distinct stocks of S. attenuata are recognizable on the basis of morphology. Further investigations of morphological-environmental variation would profit not only from increased numbers of samples, but also from the enhancement in other types of data. For example, more detailed information on food habits of the various S. attenuata forms could provide insight concerning the relationship of morphology to feeding, as well as of environmental conditions to foods available and feeding behavior of dolphins.

Body Length Variation

Perrin (1975a) indicated that onshore S. attenuata were bigger than offshore animals. Also, S. attenuata in the southern areas were reported to be about 2.5 cm shorter than those to the north (Perrin, Sloan and Henderson 1979). Our data (Appendix 3.01 and 3.02) support these ideas. For example, it is clear that male S. attenuata in the onshore block 0509 are considerably bigger than individuals from other locations. Also, means for blocks below the equator are lower than those in northern localities. The lack of significant geographic pattern in male S. attenuata suggests that it is not possible to make further, general statements concerning

geographic trends in body length. Likewise, the data for females--with a relatively weak local patterning--do not exhibit any other pronounced patterns that go in significant ways beyond those described above.

Stenella longirostris

Seasonal Variation

Considerably less is known about seasonal variation and movements of S. longirostris than for S. attenuata. Norris (1967) observed that herds of S. longirostris were consistently found off limited coastal stretches of Oahu, Hawaii. Home ranges of five groups were tentatively recognized. Perrin, Evans and Holts (1979) reported on tagging and release of 324 S. longirostris in the Eastern Tropical Pacific. They recorded seven recaptures made from less than a day to 776 days after release. Movement was from 12 to 275 n.mi., which is less than the length or width of 5⁰ blocks employed in our study. These net movements were generally less than those obtained for S. attenuata.

The analysis for seasonal effects of seven blocks, for which we had sufficient samples, did not show seasonal effects for any of the 36 characters, although two of the tooth counts had interactive effects of block and season. Sample sizes were lower than for S. attenuata in our study and, thus, the finding of fewer significant interactions could in part be due to this factor. However, if seasonal and other movements of S. longirostris were somewhat less than in S. attenuata and/or if movement directions were similar over most of the range of S. longirostris, one would obtain a result similar to ours. More extensive samples are needed in order to analyze seasonal block differences and movements in detail for S. longirostris.

Sexual Dimorphism

Perrin (1975b) was able to demonstrate only a minor degree of sexual dimorphism in S. longirostris given the limited samples available at that time. He showed that females had longer snouts, and tests indicated statistical differences between sexes in a few characters involving the braincase, feeding apparatus, and postcranial skeleton. However, he suggested "that all or most of the 'differences' result from chance alone, that is, from the large number of simultaneous tests," and concluded that sexual dimorphism was in general negligible. Given that 13 or 36 skull characters in our studies exhibited significant sexual dimorphism, we conclude that such differentiation is characteristic of this species in the Eastern Tropical Pacific. Correction for sexual differences can be helpful in the evaluation of geographic and other factors. Overall, dimorphism was less marked in S. longirostris than in S. attenuata. However, the trends in sexual dimorphism for the two species are basically the same, indicating that common behavioral and/or ecological factors are influencing morphological character variability in these two species.

Geographic Variation

Information on geographic variation in S. longirostris is less detailed than for S. attenuata, in large part because of the general paucity of specimens. Perrin (1972) conducted a broad brush analysis of geographic variation in color patterns of this species in the eastern Pacific Ocean. He found geographic variation, particularly in the "dorsal field system" of coloration, which overlies a basic general pattern. These and other data suggested differentiation in eastern, whitebelly, and Hawaiian forms. The differences were analyzed further by Perrin (1975a,b) who indicated that the whitebelly form was in some ways similar to the

Hawaiian form, but had a proportionately smaller snout. Perrin (1975b) defined four races--the three mentioned above plus a Costa Rican form which occurs off the coast of Central America. More recently, Perrin, Sloan and Henderson (1979) evaluated possible differentiation in S. longirostris involving animals found south of the equator in the eastern Pacific Ocean. They concluded that these S. longirostris just to the north; characteristics showing such a trend include some involving coloration, size, shape, and skeletal measures.

Since the analysis by Perrin, Sloan and Henderson (1979), a considerable number of additional specimens from the southern localities have become available (see Fig. 3). Our studies strongly confirm the presence of marked differentiation of a southern form from populations to the north. Loadings on principal component I (Table 9; Appendix 2.41) indicate the pervasive nature of these differences, with at least 29 of the 36 characters being involved. Such differentiation is undoubtedly due at least in part to restricted genetic interchange between populations north and south of the equator. Certainly, in terms of management, the southern area and its S. longirostris should be evaluated and treated separately.

The Costa Rican form also deviates from other S. longirostris, as is indicated by the contrast of block 0508 from others in projections onto principal component II (Fig. 21; Appendix 2.42). Associations with this component--summarized in Table 19--show that these animals have longer tooththrows and greater numbers of teeth than S. longirostris from adjacent areas. In some analyses (for example, Fig. 25), block 0508 was the most divergent; in other cases, it was the most distinctive after the division between northern and southern populations (Figs. 24 and 26). Perrin's (1975b) characterization of the Costa Rican form indicated that it has a longer, more attenuate snout, which is also suggested by our analyses. The

diagnosis of this form is still based on very few specimens; while the differences are marked, more specimens should be obtained.

Data on external color patterns are unavailable for many of the skeletal specimens and, as a result, our analyses did not take into account this characteristic. Therefore, we were not able to investigate precisely differences between eastern and whitebelly types of S. longirostris described previously (Perrin 1972, 1975a,b). These two forms overlap in geographic range and are distinguished mainly on the basis of modal color patterns in observed dolphin schools. It is the case that in our data for S. longirostris east-west trends in geographic variation of some characters were evident. Very few specimens are available from west of 110° longitude. The most westerly locality in our study (block 0501) sometimes showed its strongest affinities with the southern blocks (see Fig. 21), while at other times it grouped with the blocks north of the equator. Additional collecting from western areas would enable investigators to more clearly evaluate geographic variation in the species, thereby providing more detailed information on areas where the whitebelly S. longirostris are likely to be found.

Morphological-Environmental Covariation

As with offshore S. attenuata, we found numerous statistically significant associations of environmental and morphological variables in S. longirostris. Again, Solar Insolation(Jan.) which has a distinct north-to-south trend covaries with many (69%) of the morphological characteristics analyzed. Sea Surface Temp.(July) exhibits a geographic pattern that corresponds with most (77%) of the skull variables; correlations with several skull width measures were almost -0.9. Chance

associations at this level are highly unlikely. Measures of temperature variation also are associated with numerous morphological patterns.

The rather marked morphological covariation between S. attenuata and S. longirostris involving a number of characters could reflect common causes associated with environmental spatial variation. Expansion of samples and numbers of samples would be helpful in the further evaluation of the extent of covariation for the two species and how it relates to common responses to environmental differences. The demonstrated close associations of environmental and morphological variables goes considerably beyond what has heretofore been demonstrated in marine mammals.

Body Length Variation

For S. longirostris, Perrin (1975b) showed that whitebellied animals were 4 to 5 cm larger than eastern individuals. The Costa Rican form was also shown as being relatively large (Perrin 1975b). More recently (Perrin, Sloan and Henderson 1979) it was demonstrated that southern males and females are 2 to 3 cm longer than those classified as northern whitebelly S. longirostris.

Data used in our analyses confirm some of these trends. For example, the animals are larger south of the equator than in the north (Appendices 3.03 and 3.04). While the Costa Rican form may well be relatively large, the combined data we used do not indicate such a trend.

Our statistical findings support the point made by Perrin, Sloan and Henderson (1979) that geographic changes in body lengths are not in parallel between S. longirostris and S. attenuata. As they indicated, it is highly unlikely that with size changes occurring in opposite directions they are due to differential exploitation that might affect age and length at maturity. Rather such differences are much more likely to be characteristic of the two species.

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LITERATURE CITED

- Au, D.W.K., W.L. Perryman, and W.F. Perrin. 1979. Dolphin distribution and the relationship to environmental features in the eastern tropical Pacific. Southwest Fisheries Center, Natl. Ocean. Atmos. Admin., La Jolla, California. Admin. Rep. No. LG-79-43.
- Bartholomew, J. and Son. 1975. The Times atlas of the world. Comprehensive Edition. Times Books, London.
- Brodie, P.F. 1975. Cetacean energetics, an overview of intraspecific size variation. Ecology 56:152-161.
- Brodie, P.F. 1977. Form, function and energetics of Cetacea: a discussion. Pages 45-58 in R.T. Harrison (ed.), Functional anatomy of marine mammals. Vol. 3. Academic Press, New York.
- Brunt, D. 1934. Physical and dynamical meteorology. University Press, Cambridge, England.
- Cromwell, T. 1958. Thermocline topography, horizontal current and "ridging" in the eastern tropical Pacific. Inter-Am. Trop. Tuna Comm. Bull. 3:135-152.
- Dailey, M.D., and W.F. Perrin. 1973. Helminth parasites of porpoises of the genus Stenella in the eastern tropical Pacific, with descriptions of two new species: Mastigonema stenellae gen. et sp. n. (Nematoda:Spiruroidea) and Zalophotrema pacificum sp. n. (Trematoda:Digenea). Fish. Bull. (U.S.) 71:455-471.
- Dixon, W.D., and M.B. Brown (eds.). 1979. BMDP-79. Biomedical computer programs. P-series. Univ. California Press, Berkeley, California.

- Evans, W.E. 1971. Orientation behavior of delphinids: radio telemetric studies. Ann. N.Y. Acad. Sci. 188:142-160.
- Evans, W.E. 1974. Radio-telemetric studies of two species of small odontocete cetaceans. Pages 385-394 in W.E. Schevill (ed.), The whale problem. A status report. Harvard Univ. Press, Cambridge, Massachusetts.
- Fischer, P. 1881. Cetaces du Sud-ouest de la France. Actes Soc. Linn. Bordeaux 35 (Quatrieme serie: 5):5-219 + Pl. 1-8.
- Gould, S.J., and R.F. Johnston. 1972. Geographic variation. Ann. Rev. Ecol. Syst. 3:457-489.
- Henderson, J.R., W.F. Perrin, and R.B. Miller. 1980. Rate of gross annual production in dolphin populations (Stenella spp. and Delphinus delphis) in the eastern tropical Pacific, 1973-1978. Southwest Fisheries Center, Natl. Ocean. Atmos. Admin., La Jolla, California. Admin. Rep. LJ-80-02.
- Innis, G., J. Haefner, G. Worthen, and C. Fowler. 1979. ETP ecosystem model documentation. Report for Southwest Fisheries Center, Natl. Ocean. Atmos. Admin., La Jolla, California. 112p.
- Katz, J.O., and F.J. Rohlf. 1973. Function-point cluster analysis. Syst. Zool. 22:295-301.
- Mantel, N. 1967. The detection of disease clustering and a generalized regression approach. Cancer Res. 27:209-220.
- Norris, K.S. 1967. Some observations on the migration and orientation of marine mammals. Pages 101-125 in R.M. Storm (ed.), Animal

orientation and navigation. Oregon State Univ. Press,
Corvallis, Oregon.

Perrin, W.F. 1972. Color patterns of spinner porpoises (Stenella cf. S. longirostris) of the eastern Pacific and Hawaii, with comments on delphinid pigmentation. Fish. Bull. (U.S.) 70:983-1003.

Perrin, W.F. 1975a. Distribution and differentiation of populations of dolphins of the genus Stenella in the eastern tropical Pacific. J. Fish. Res. Bd. Can. 32:1059-1067.

Perrin, W.F. 1975b. Variation of spotted and spinner porpoise (genus Stenella) in the eastern tropical Pacific and Hawaii. Bull. Scripps Inst. Oceanogr. 21:1-206.

Perrin, W.F., J.M. Coe, and J.R. Zweifel. 1976. Growth and reproduction of the spotted porpoise, Stenella attenuata, in the offshore eastern tropical Pacific. Fish. Bull. (U.S.) 74:229-269.

Perrin, W.F., W.E. Evans, and D.B. Holt. 1979. Movements of pelagic dolphins (Stenella spp.) in the eastern tropical Pacific as indicated by results of tagging, with summary of tagging operations, 1969-1976. U.S. Dep. Commerce. NOAA Tech. Rep. NMFS SSRF-737. 14p.

Perrin, W.F., and J.R. Henderson. 1979. Growth and reproductive rates in two populations of spinner dolphins, Stenella longirostris, with different histories of exploitation. Status of Porpoise Stocks Workshop, 27-31 August 1979. Southwest Fisheries Center, Natl. Ocean. Atmos. Admin., La Jolla, California.

Admin. Rep. No. LJ-79-29.

Perrin, W.F., D.B. Holts, and R.B. Miller. 1977. Growth and reproduction of the eastern spinner dolphin, a geographical form of Stenella longirostris in the eastern tropical Pacific. Fish. Bull. (U.S.) 75:725-750.

Perrin, W.F., P.A. Sloan, and J.R. Henderson. 1979. Taxonomic status of the 'southwestern stocks' of spinner dolphin, Stenella longirostris, and spotted dolphin, S. attenuata. Rep. Int. Whal. Comm. 29:175-184.

Rohlf, F.J. 1970. Adaptive hierarchical clustering schemes. Syst. Zool. 19:58-82.

Rohlf, F.J., J. Kishpaugh, and D. Kirk. 1979. NT-SYS. Numerical taxonomy system of multivariate statistical programs. State Univ. New York, Stony Brook, New York.

Sneath, P.H.A., and R.R. Sokal. 1973. Numerical taxonomy. W.H. Freeman and Co., San Francisco.

Sokal, R.R. 1979. Testing statistical significance of geographic variation patterns. Syst. Zool. 28:227-232.

True, F.W. 1889. Contributions to the natural history of the cetaceans, a review of the family Delphinidae. Bull. U.S. Natl. Mus. 36:1-191.

U.S. Dep. Commerce. 1977. Aerial survey trip report. January-June 1977. Southwest Fisheries Center, Natl. Ocean. Atmos. Admin., La Jolla, California. Admin. Rep. No. LJ-78-01.

Volkov, A.F., and I.F. Moroz. 1977. Oceanological conditions of the distribution of Cetacea in the eastern tropical part of the Pacific Ocean. Rep. Int. Whal. Comm. 27:186-188.

Wirth, M., G.F. Estabrook, and D.F. Rogers. 1966. A graph theory model for systematic biology with an example for the Oncidiinae (Orchidaceae). Syst. Zool. 15:59-69.

Wyrтки, K. 1964. The thermal structure of the eastern Pacific Ocean. Supplement Dtsch. Hydrogr. Z., Series A, 8(6). 85p.

Wyrтки, K. 1967. Circulation and water masses in the eastern equatorial Pacific Ocean. Int. J. Oceanol. Limnol. 1:117-147.

Table 1(1/3). List of skull and mandibular measurements.^a

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1. Condylobasal L.--From tip of rostrum to hindmost margin of occipital condyles (1).
 2. L. Rostrum(frm.Base)--From tip of rostrum to line across hindmost limits of antorbital notches (2).
 3. L. Rostrum(frm.Pterygoid)--Distance from tip of rostrum to mesial end of posterior margin of right pterygoid (9).
 4. W. Rostrum(at Base)--Measured along line across hindmost limit of antorbital notches (3).
 5. W. Rostrum(at 1/4 L.)--Width of rostrum measured at one-fourth distance from line across hindmost limits of antorbital notches.
 6. W. Rostrum(at 1/2 L.)--Width of rostrum measured at midlength (5).
 7. W. Premax.(at 1/2 L.)--Width of premaxillaries at midlength of rostrum (6).
 8. W. Rostrum(at 3/4 L.)--Width of rostrum at three-fourths distance from posterior end (7).
 9. Preorbital W.--Greatest preorbital width (10).
 10. Postorbital W.--Greatest postorbital width (11).
 11. Skull W.(at Zygomatic P.)--Greatest width across zygomatic processes of squamosal (14).
 12. Skull W.(at Parietals)--Greatest parietal width, within temporal fossae (16).
 13. Ht. Braincase--Vertical external height of braincase from midline of basisphenoid to summit of supraoccipital (but not including crest) (17).

Table 1(2/3). List of skull and mandibular measurements.^a

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14. L. Braincase--Internal length of braincase from hindmost limit of occipital condyles to foremost limit of cranial cavity along midline of skull (18).
 15. Max. W. Premax.--Greatest width of premaxillaries (15).
 16. W. External Nares--Greatest width of external nares (13).
 17. W. Lf. Premax.(md.Nares)--Maximum width of left premaxillary, measured from most anterior point on narial midline
 18. W. Rt. Premax.(md.Nares)--Maximum width of right premaxillary, measured from most anterior point on narial midline.
 19. L. Temporal Fossa--Greatest length of left temporal fossa, measured to external margin of raised suture (19).
 20. W. Temporal Fossa--Greatest width of left temporal fossa at right angles to greatest length (20).
 21. Orbital L.--Length of left orbit from apex of preorbital process of frontal to apex of postorbital process (25).
 22. L. Antorbital P.--Length of antorbital process of left lacrimal (26).
 23. Sep. Pterygoids--Maximum separation of pterygoids, measured between mesial ends of left and right processes.
 24. W. Internal Nares--Greatest width of internal nares (27).
 25. L. Lf. Tympanic Cavity--Length from left pterygobasioccipital suture to furthest point on left exoccipital.
 26. L. Rt. Tympanic Cavity--Length from right pterygobasioccipital suture to furthest point on right exoccipital.
 27. W. at Pterygo. Sutures--Greatest distance between left and right pterygobasioccipital sutures.

Table 1(3/3). List of skull and mandibular measurements.^a

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28. L. Up. Toothrow--from hindmost margin of hindmost alveolus on left side to tip of rostrum (32).
29. No. Teeth(Up.Lf.)--Number of teeth, upper left (33).
30. No. Teeth(Up.Rt.)--Number of teeth, upper right (34).
31. No. Teeth(Low.Lf.)--Number of teeth, lower left (35).
32. No. Teeth(Low.Rt.)--Number of teeth, lower right (36).
33. L. Low. Toothrow--from hindmost margin of hindmost alveolus on left ramus to tip of mandible (37).
34. Ht. Ramus--Greatest height of left ramus at right angles to greatest length (39).
35. Tooth W.--Width of a tooth located at two-thirds distance from mandibular tip.
36. L. Ramus--Greatest length of left ramus (38).
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^aAbbreviations: frm.=from; Ht.=height; L.=length; Lf.=left; Low.=lower; Max.=maximum; md.=midline; No.=number; P.=process; Premax.=premaxillary; Pterygo.=pterygobasioccipital; Rt.=right; Sep.=separation; Up.=upper; W.=width. Numbers following measurement descriptions refer to equivalent character numbers of Perrin (1975b).

Table 2(1/2). List of environmental measurements for each 5° block of the eastern tropical Pacific Ocean.^a

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1. Sea Current(N.,Winter)--Average northern component (in knots) of the surface water current in winter (Innis et al. 1978: their Fig. 2.2).
 2. Sea Current(W.,Winter)--Average western component (in knots) of the surface water current in winter (Innis et al. 1978: Fig. 2.3)
 3. Water Depth--Average sea depth(in m; Bartholomew 1975: Fig. 122).
 4. Solar Insolation(Jan.)--Average incoming solar radiation for January (in gm cal/cm; Brunt 1934: Table 2)
 5. Solar Insolation(Annual)--Average annual incoming solar radiation (in gm cal/cm; Brunt 1934: Table 2)
 6. Sea Surface Temp.(Jan.)--Average January sea surface temperature (in C; Wyrтки 1964: Fig. 2).
 7. Sea Surface Temp.(July)--Average July sea surface temperature (in C; Wyrтки 1964: Fig. 8).
 8. Sea Surface Temp.(Ann. Var.)--Average annual sea surface temperature variation (in C; Wyrтки 1964: Fig. 26)
 9. Oxygen Min. Layer(Depth)--Average depth (in m) at which oxygen content of sea water falls below 1.0 ml/l (Wyrтки 1967: Fig. 11a).
 10. Oxygen Min. Layer(Thick.)--Thickness (in m) of the subsurface layer with an oxygen content of less than 1.0 ml/l (Wyrтки 1967: Fig. 11b)
 11. Surface Salinity--Average salinity (o/oo) of surface sea water (Wyrтки 1967: Fig. 3).
 12. Thermocline Depth(Winter)--Average depth (in m) of the mixed layer for January, February, and March (Wyrтки, 1964: Figs. 29, 30 and 31).

Table 2(2/2). List of environmental measurements for each 5° block of the eastern tropical Pacific Ocean.^a

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13. Thermocline Depth(Summer)--Average summer depth (in m) of the permanent thermocline (Cromwell 1958: Fig. 1c).
 14. Thermocline Depth(Ann. Var.)--Average annual variation in depth of the center of the permanent thermocline (in m; Wyrteki 1964: Fig. 55).
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^aAbbreviations: Ann. Var.=Annual Variation; Jan.=January; Min.=Minimum; N.=North; Temp.=Temperature; Thick.=Thickness; W.=West. Figure numbers in table refer to those in the original references.

Table 3(1/3). Sexual dimorphism in Stenella attenuata evaluated for 36 characters.

Character	F-value ^a	Mean ^b		Correction factor ^c	Percentage difference ^d
		Male	Female		
1 Condylbasal L.	1.72	402.32	403.66	-0.67	-0.33
2 L. Rostrum(frm.Base)	14.79***	239.38	242.48	-1.55	-1.29
3 L. Rostrum(frm.Pterygoid)	7.72**	281.60	284.25	-1.33	-0.94
4 W. Rostrum(at Base)	22.79***	85.24	83.87	0.69	1.62
5 W. Rostrum(at 1/4 L.)	47.04***	59.63	57.88	0.88	2.98
6 W. Rostrum(at 1/2 L.)	46.75***	44.41	42.93	0.74	3.39
7 W. Premax.(at 1/2 L.)	77.89***	24.14	22.76	0.69	5.88
8 W. Rostrum(at 3/4 L.)	71.85***	31.87	30.14	0.87	5.58
9 Preorbital W.	46.93***	152.28	149.46	1.41	1.87
10 Postorbital W.	42.83***	170.45	167.89	1.28	1.51
11 Skull W.(at Zygomatic P.)	47.77***	170.07	167.26	1.41	1.67
12 Skull W.(at Parietals)	62.43***	141.27	138.03	1.62	2.32
13 Ht. Braincase	63.54***	99.22	96.93	1.14	2.33
14 L. Braincase	48.85***	120.05	117.88	1.09	1.82
15 Max. W. Premax.	8.05**	67.54	66.87	0.33	1.00
16 W. External Nares	0.12	42.39	42.33	0.03	0.14

Table 3(2/3). Sexual dimorphism in Stenella attenuata evaluated for 36 characters.

Character	F-value ^a	Mean ^b		Correction factor ^c	Percentage difference ^d
		Male	Female		
17 W. Lf. Premax.(md.Nares)	15.94***	26.62	26.14	0.24	1.82
18 W. Rt. Premax.(md.Nares)	0.92	40.02	39.87	0.07	0.38
19 L. Temporal Fossa	22.22***	68.78	67.05	0.87	2.55
20 W. Temporal Fossa	30.42***	52.91	51.10	0.91	3.48
21 Orbital L.	0.08	47.44	47.39	0.02	0.11
22 L. Antorbital P.	10.24**	38.30	37.61	0.34	1.82
23 Sep. Pterygoids	0.04	1.94	1.92	0.01	1.04
24 W. Internal Nares	14.30***	48.01	47.24	0.38	1.62
25 L. Lf. Tympanic Cavity	2.30	49.30	48.95	0.18	0.71
26 L. Rt. Tympanic Cavity	3.76	49.57	49.14	0.21	0.87
27 W. at Pterygo. Sutures	1.38	46.58	46.31	0.13	0.58
28 L. Up. Toothrow	12.56***	204.69	207.36	-1.33	-1.30
29 No. Teeth(Up.Lf.)	1.59	41.29	41.08	0.10	0.51
30 No. Teeth(Up.Rt.)	0.48	40.94	40.83	0.06	0.27
31 No. Teeth(Low.Lf.)	0.00	39.89	39.89	0.00	0.00
32 No. Teeth(Low.Rt.)	1.11	39.93	40.10	-0.08	-0.42

Table 3(3/3). Sexual dimorphism in Stenella attenuata evaluated for 36 characters.

Character	F-value ^a	Mean ^b		Correction factor ^c	Percentage difference ^d
		Male	Female		
33 L. Low. Tooththrow	13.49***	198.98	201.78	-1.40	-1.40
34 Ht. Ramus	0.00	58.53	58.53	0.00	0.00
35 Tooth W.	18.37***	3.82	3.70	0.06	3.19
36 L. Ramus	10.85**	338.98	342.22	-1.62	-0.95

^aF-value from two-way analysis of variance (sex vs. 5 block) involving 11 blocks (*, P<0.05; **, P<0.01; ***, P<0.001).

^bUnweighted mean for the 11 blocks.

^cAdded to all individual female measurements and subtracted from all individual male measurements to correct for sexual differences.

^dThe difference between sexes multiplied by 100, with the resulting value divided by the average of the male and female means.

Table 4(1/2). Principal component loadings for Stenella attenuata involving character means for 23 blocks.

Character	Component	
	I	II
1 Condylbasal L.	.976	.161
2 L. Rostrum(frm.Base)	.953	.190
3 L. Rostrum(frm.Pterygoid)	.935	.191
4 W. Rostrum(at Base)	.876	-.087
5 W. Rostrum(at 1/4 L.)	.890	-.145
6 W. Rostrum(at 1/2 L.)	.906	-.048
7 W. Premax.(at 1/2 L.)	.882	-.023
8 W. Rostrum(at 3/4 L.)	.884	.033
9 Preorbital W.	.922	-.075
10 Postorbital W.	.965	-.084
11 Skull W.(at Zygomatic P.)	.967	-.076
12 Skull W.(at Parietals)	.939	.144
13 Ht. Braincase	.911	.093
14 L. Braincase	.881	.168
15 Max. W. Premax.	.939	-.095
16 W. External Nares	.919	.034
17 W. Lf. Premax.(md.Nares)	.960	-.107
18 W. Rt. Premax.(md.Nares)	.783	-.068
19 L. Temporal Fossa	.863	.221
20 W. Temporal Fossa	.757	.183
21 Orbital L.	.903	.153
22 L. Antorbital P.	.928	-.060
23 Sep. Pterygoids	.796	-.090

Table 4(2/2). Principal component loadings for Stenella attenuata involving character means for 23 blocks.

Character	Component	
	I	II
24 W. Internal Nares	.856	.001
25 L. Lf. Tympanic Cavity	.864	-.011
26 L. Rt. Tympanic Cavity	.866	-.048
27 W. at Pterygo. Sutures	.907	-.085
28 L. Up. Toothrow	.944	.248
29 No. Teeth(Up.Lf.)	-.422	.751
30 No. Teeth(Up.Rt.)	-.386	.791
31 No. Teeth(Low.Lf.)	-.389	.852
32 No. Teeth(Low.Rt.)	-.300	.870
33 L. Low. Toothrow	.944	.261
34 Ht. Ramus	.965	.159
35 Tooth W.	.902	-.009
36 L. Ramus	.969	.175

Table 5(1/2). One-way analysis of variance tests for each of 36 measurements for onshore versus offshore population of Stenella attenuata.

Character	F-value	Mean ^a	
		Offshore	Onshore
1 Condylbasal L.	339.70***	396.06	436.73
2 L. Rostrum(frm.Base)	212.95***	237.12	262.27
3 L. Rostrum(frm.Pterygoid)	148.50***	279.00	304.37
4 W. Rostrum(at Base)	124.50***	82.98	90.52
5 W. Rostrum(at 1/4 L.)	141.47***	57.18	64.23
6 W. Rostrum(at 1/2 L.)	178.41***	42.16	48.94
7 W. Premax.(at 1/2 L.)	134.54***	22.65	26.71
8 W. Rostrum(at 3/4 L.)	157.96***	29.63	35.57
9 Preorbital W.	206.46***	147.73	161.42
10 Postorbital W.	293.96***	165.85	181.38
11 Skull W.(at Zygomatic P.)	278.98***	165.27	180.85
12 Skull W.(at Parietals)	123.96***	138.28	147.83
13 Ht. Braincase	276.10***	96.48	106.60
14 L. Braincase	353.24***	116.37	129.25
15 Max. W. Premax.	162.58***	65.78	72.26
16 W. External Nares	161.25***	41.41	46.05
17 W. Lf. Premax.(md.Nares)	199.39***	25.70	29.33
18 W. Rt. Premax.(md.Nares)	69.18***	39.13	41.99
19 L. Temporal Fossa	348.31***	65.82	81.06
20 W. Temporal Fossa	194.82***	50.67	61.02
21 Orbital L.	66.85***	46.88	49.98
22 L. Antorbital P.	108.09***	36.80	41.70
23 Sep. Pterygoids	104.04***	1.77	3.33

Table 5(2/2). One-way analysis of variance tests for each of 36 measurements for onshore versus offshore population of Stenella attenuata.

Character	F-value	Mean ^a	
		Offshore	Onshore
24 W. Internal Nares	135.53***	46.40	51.57
25 L. Lf. Tympanic Cavity	92.63***	48.19	52.88
26 L. Rt. Tympanic Cavity	94.24***	48.52	53.08
27 W. at Pterygo. Sutures	174.09***	45.12	51.74
28 L. Up. Toothrow	204.22***	202.86	225.62
29 No. Teeth(Up.Lf.)	7.85**	41.37	40.44
30 No. Teeth(Up.Rt.)	6.32*	41.18	40.30
31 No. Teeth(Low.Lf.)	5.66*	40.21	39.41
32 No. Teeth(Low.Rt.)	4.87*	40.22	39.47
33 L. Low. Toothrow	218.43***	197.02	220.83
34 Ht. Ramus	391.20***	57.15	65.98
35 Tooth W.	463.68***	3.51	4.73
36 L. Ramus	277.77***	335.48	370.58

*, P<0.05; **, P<0.01; ***, P<0.001; df = 1, 603.

^aUnweighted mean of 574 offshore and 31 onshore specimens.

Table 6. Statistics for step-wise discriminant analysis of offshore and onshore Stenella attenuata.

Character	F-value to enter	Order of entry	Coefficients ^a	Classification function ^b	
				Offshore	Onshore
14 L. Braincase	73.17	3	0.0738	6.274	6.740
17 W. Lf. Premax.(md.Nares)	17.26	7	0.1403	6.551	7.439
19 L. Temporal Fossa	15.79	6	0.0577	-0.588	-0.223
22 L. Antorbital P.	4.12	9	0.0425	1.686	1.955
23 Sep. Pterygoids	26.78	4	0.3211	1.780	3.810
29 No. Teeth(Up.Lf.)	5.62	8	-0.0670	11.260	10.836
33 L. Low. Toothrow	24.32	5	0.0236	0.875	1.025
34 Ht. Ramus	164.81	2	0.0927	5.403	5.990
35 Tooth W.	463.68	1	1.4953	23.224	32.677
Constant			-30.8694	-997.567	-1190.655

^aFor canonical variable, which in the two-group case is equivalent to the discriminant function between the two groups.

^bUsed with original measurements (corrected to zwitter values). Add products of zwitter values and function values to constant; classify as offshore or onshore depending on which results in lower value for classification function.

Table 7(1/2). Principal component loadings for offshore Stenella attenuata involving character means for 19 blocks.

Character	Component	
	I	II
1 Condylbasal L.	.837	-.361
2 L. Rostrum(frm.Base)	.793	-.265
3 L. Rostrum(frm.Pterygoid)	.852	-.173
4 W. Rostrum(at Base)	.861	.165
5 W. Rostrum(at 1/4 L.)	.915	.203
6 W. Rostrum(at 1/2 L.)	.884	.042
7 W. Premax.(at 1/2 L.)	.892	.031
8 W. Rostrum(at 3/4 L.)	.779	.009
9 Preorbital W.	.900	.199
10 Postorbital W.	.947	.167
11 Skull W.(at Zygomatic P.)	.962	.152
12 Skull W.(at Parietals)	.079	-.927
13 Ht. Braincase	-.089	-.374
14 L. Braincase	-.444	-.110
15 Max. W. Premax.	.868	.039
16 W. External Nares	.589	-.177
17 W. Lf. Premax.(md.Nares)	.752	.046
18 W. Rt. Premax.(md.Nares)	.811	.154
19 L. Temporal Fossa	-.616	-.642
20 W. Temporal Fossa	-.676	-.330
21 Orbital L.	.688	-.467
22 L. Antorbital P.	.864	.253
23 Sep. Pterygoids	-.098	-.792

Table 7(2/2). Principal component loadings for offshore Stenella attenuata involving character means for 19 blocks.

Character	Component	
	I	II
24 W. Internal Nares	.477	.305
25 L. Lf. Tympanic Cavity	.131	-.536
26 L. Rt. Tympanic Cavity	.205	-.586
27 W. at Pterygo. Sutures	.422	.597
28 L. Up. Toothrow	.627	-.580
29 No. Teeth(Up.Lf.)	-.050	-.459
30 No. Teeth(Up.Rt.)	.073	-.708
31 No. Teeth(Low.Lf.)	-.379	-.731
32 No. Teeth(Low.Rt.)	-.308	-.678
33 L. Low. Toothrow	.543	-.607
34 Ht. Ramus	.633	-.518
35 Tooth W.	.300	-.463
36 L. Ramus	.781	-.468

Table 8. Step-wise discriminant analysis of all specimens from 19 offshore blocks for Stenella attenuata.

Character	F-value to enter	Order of entry	Coefficients ^a	
			1	2
3 L. Rostrum(frm.Pterygoid)	3.04	5	0.0076	-0.0816
10 Postorbital W.	9.79	2	-0.1773	-0.0347
14 L. Braincase	2.80	4	0.0674	0.1770
17 W. Lf. Premax.(md.Nares)	2.49	6	-0.1051	-0.0386
18 W. Rt. Premax.(md.Nares)	2.35	7	-0.1289	0.2096
19 L. Temporal Fossa	4.18	3	0.1191	0.0855
20 W. Temporal Fossa	7.82	1	0.1231	-0.0850
Constant			13.1173	-14.0827

^aFor canonical variables.

Table 9(1/2). Association of interlocality character differences with geographic distances (in nautical miles) and the reciprocals of these distances. Results from Mantel tests and matrix correlations for offshore Stenella attenuata.

Character	Distance		Reciprocal of distance	
	<u>t</u>	<u>r</u>	<u>t</u>	<u>r</u>
1 Condylobasal L.	1.81	.237	-1.60	-.161
2 L. Rostrum(frm.Base)	1.70	.224	-1.57	-.159
3 L. Rostrum(frm.Pterygoid)	2.38*	.302	-2.67**	-.263
4 W. Rostrum(at Base)	4.28***	.496	-4.44***	-.414
5 W. Rostrum(at 1/4 L.)	3.71***	.420	-4.74***	-.436
6 W. Rostrum(at 1/2 L.)	3.22**	.388	-4.02***	-.384
7 W. Premax.(at 1/2 L.)	2.39*	.300	-2.88**	-.282
8 W. Rostrum(at 3/4 L.)	1.51	.201	-1.92	-.195
9 Preorbital W.	5.57***	.577	-6.20***	-.544
10 Postorbital W.	5.75***	.604	-6.13***	-.542
11 Skull W.(at Zygomatic P.)	5.80***	.609	-6.34***	-.560
12 Skull W.(at Parietals)	1.00	.121	-1.64	-.156
13 Ht. Braincase	0.93	.104	-1.04	-.095
14 L. Braincase	0.45	.053	-0.47	-.044
15 Max. W. Premax.	4.52***	.503	-4.39***	-.400
16 W. External Nares	3.61***	.412	-4.27***	-.395
17 W. Lf. Premax.(md.Nares)	1.95	.223	-1.77	-.164
18 W. Rt. Premax.(md.Nares)	4.96***	.573	-5.08***	-.473
19 L. Temporal Fossa	3.78***	.359	-4.41***	-.370
20 W. Temporal Fossa	3.63***	.417	-4.22***	-.392

Table 9(2/2). Association of interlocality character differences with geographic distances (in nautical miles) and the reciprocals of these distances. Results from Mantel tests and matrix correlations for offshore *Stenella attenuata*.

Character	Distance		Reciprocal of distance	
	<u>t</u>	<u>r</u>	<u>t</u>	<u>r</u>
21 Orbital L.	2.26*	.278	-3.09**	-.299
22 L. Antorbital P.	3.77***	.395	-4.70***	-.415
23 Sep. Pterygoids	0.22	.027	-1.05	-.102
24 W. Internal Nares	0.90	.110	-1.73	-.167
25 L. Lf. Tympanic Cavity	0.60	.079	-1.14	-.115
26 L. Rt. Tympanic Cavity	0.87	.112	-1.32	-.130
27 W. at Pterygo. Sutures	2.00*	.220	-2.30*	-.208
28 L. Up. Toothrow	1.61	.201	-1.44	-.140
29 No. Teeth(Up.Lf.)	0.52	.069	-1.02	-.103
30 No. Teeth(Up.Rt.)	-0.17	-.022	-0.67	-.066
31 No. Teeth(Low.Lf.)	1.76	.187	-2.12*	-.188
32 No. Teeth(Low.Rt.)	2.28*	.260	-2.64**	-.243
33 L. Low. Toothrow	1.18	.133	-0.78	-.072
34 Ht. Ramus	0.10	.012	-0.19	-.018
35 Tooth W.	0.63	.081	-1.05	-.105
36 L. Ramus	1.55	.202	-1.55	-.155
Component I	4.61***	.499	-5.23***	-.470
Component II	1.31	.154	-1.91	-.179
Canonical Variable 1	6.69***	.592	-6.96***	-.566
Canonical Variable 2	1.88	.194	-2.16*	-.189

*, P<0.05; **, P<.01; ***, P<0.001.

Table 10. Association of interlocality character differences with geographic distances (in nautical miles) and the reciprocals of these distances. Results from Mantel tests and matrix correlations for 832 specimens in 20 blocks for offshore Stenella attenuata.

Character	Distance		Reciprocal of distance	
	<u>t</u>	<u>r</u>	<u>t</u>	<u>r</u>
29 No. Teeth(Up.Lf.)	0.64	.076	-1.05	-.098
30 No. Teeth(Up.Rt.)	-0.07	-.009	-0.92	-.084
31 No. Teeth(Low.Lf.)	2.22*	.211	-2.92**	-.240
32 No. Teeth(Low.Rt.)	1.98*	.211	-2.61**	-.240

*, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$.

Table 11(1/3). Product-moment correlations of block means for morphological and environmental variables based on 19 blocks of offshore Stenella attenuata.^a

Character	1	2	3	4	5	Environmental variable ^b								
						6	7	8	9	10	11	12	13	14
1 Condylobasal L.	-													
2 L. Rostrum(frm.Base)	-				+									
3 L. Rostrum(frm.Pterygoid)				+	+					-			+	
4 W. Rostrum(at Base)				+++	+	-	-			-	++		++	
5 W. Rostrum(at 1/4 L.)	+			+++	+++	---	---	++		---	++		+	
6 W. Rostrum(at 1/2 L.)	++			+++	+	---	---	++		---	++			
7 W. Premax.(at 1/2 L.)				++	+	-	-			-	+			
8 W. Rostrum(at 3/4 L.)	+++			++	++	---	---	+		---				
9 Preorbital W.			++	+++	+++	---	---	+		---	++		+	
10 Postorbital W.			+	+++	++	---	---	+		---	++		++	
11 Skull W.(at Zygomatic P.)			+	+++	++	---	---	+		---	++		++	
12 Skull W.(at Parietals)					-	++		+		++				
13 Ht. Braincase										+				
14 L. Braincase				-	---		---			+				
15 Max. W. Premax.				+++	+	-		+		-	++		+	

Table 11(2/3). Product-moment correlations of block means for morphological and environmental variables based on 19 blocks of offshore Stenella attenuata.^a

Character	1	2	3	4	5	6	7	8	Environmental variable ^b					11	12	13	14
									9	10	10	11	12				
16 W. External Nares	-																
17 W. Lf. Premax.(md.Nares)				+													
18 W. Rt. Premax.(md.Nares)				+++		--	---	++		-	+++	+++			+		
19 L. Temporal Fossa				---	--	+++	+++	--		+++	---				--		
20 W. Temporal Fossa	--			---	---	+++	+++	---		+++	--		+				
21 Orbital L.																	
22 L. Antorbital P.	++			+++	+++	---	---	++		---	++			+			
23 Sep. Pterygoids										+				--			
24 W. Internal Nares	++			+	+	--	--	+		---	+						
25 L. Lf. Tympanic Cavity																	
26 L. Rt. Tympanic Cavity			+														
27 W. at Pterigo. Sutures				+	++	--	-			--							
28 L. Up. Toothrow		-															
29 No. Teeth(Up.Lf.)	+++																
30 No. Teeth(Up.Rt.)	++																

Table 11(3/3). Product-moment correlations of block means for morphological and environmental variables based on 19 blocks of offshore Stenella attenuata.^a

Character	1	2	3	4	5	6	7	8	9	10	11	12	13	14
31 No. Teeth(Low.Lf.)				-	-	+				+	-	-	-	+
32 No. Teeth(Low.Rt.)				-		+					-	-	-	+
33 L. Low. Toothrow		-												
34 Ht. Ramus	+													
35 Tooth W.	++													
36 L. Ramus		-												
Component I				+++	++	-	--			--	+	+	+	
Component II				+	+	--	-			--				-
Canonical Variable 1				---	---	+++	+++	--		+++	---	-	-	
Canonical Variable 2														

^a Blanks indicate nonsignificant correlations. Individual symbols refer to significant positive or negative correlations ($P < 0.05$; greater than 0.456), double symbols indicate highly significant correlations ($P < 0.01$; greater than 0.575), and triple symbols represent very highly significant correlations ($P < 0.001$; greater than 0.693).

^b Environmental variables as numbered in Tables 2 and 12.

Table 12. Results of Mantel tests(t) and matrix correlation (r) for offshore Stenella attenuata. Comparison of interlocality differences for 14 environmental variables against those for the first five morphological variables entered into a step-wise multiple discriminant analysis.

Environmental variable	W. Temporal		Postorbital W.		L. Temporal		L. Braincase		L. Rostrum	
	<u>t</u>	<u>r</u>	<u>t</u>	<u>r</u>	<u>t</u>	<u>r</u>	<u>t</u>	<u>r</u>	<u>t</u>	<u>r</u>
1 Sea Current(N.,Winter)	3.10**	.533	0.29	.045	-0.18	.024	0.88	.163	-0.05	-.011
2 Sea Current(W.,Winter)	-1.23	-.173	0.12	.002	-1.14	-.124	-0.12	-.061	1.13	.179
3 Water Depth	0.92	.134	2.27*	.292	-0.33	-.037	0.94	.141	0.97	.159
4 Solar Insolation(Jan.)	6.12***	.641	6.38***	.620	6.55***	.588	1.76	.188	0.71	.081
5 Solar Insolation(Ann.)	3.18**	.376	3.13**	.337	3.03**	.293	2.83**	.343	1.06	.139
6 Sea Surface Temp.(Jan.)	6.09***	.648	3.75***	.369	7.29***	.661	-0.11	-.012	-0.74	-.086
7 Sea Surface Temp.(July)	6.42***	.757	4.17***	.448	5.57***	.538	-0.13	-.016	-0.34	-.045
8 Sea Surface Temp.(Ann.Var.)	5.38***	.655	3.36***	.371	3.88***	.383	-0.60	-.075	0.06	-.008
9 Oxygen Minimum Layer(Depth)	-0.65	-.068	-0.20	-.020	-0.96	-.086	0.75	.079	0.25	.028
10 Oxygen Minimum Layer(Thick.)	4.79***	.529	3.46**	.352	5.85***	.542	0.49	.055	0.50	.061
11 Surface Salinity	3.57***	.386	3.54***	.354	5.46***	.500	-1.17	-.129	-0.14	-.017
12 Thermocline Depth(Winter)	0.74	.089	0.64	.070	-0.15	-.015	-0.13	-.017	0.67	.090
13 Thermocline Depth(Summer)	0.22	.022	3.09**	.290	3.47***	.304	-0.33	-.034	1.34	.145
14 Thermocline Depth(Ann.Var.)	0.11	.014	0.68	.075	0.60	.059	-0.61	-.075	-1.33	-.178

*, P<0.05; **, P<0.01; ***, P<0.001.

Table 13. Product-moment correlations of block means for morphological and environmental variables based on 832 specimens for 20 blocks of offshore Stenella attenuata.^a

Character	Environmental variable ^b													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
29 No. Teeth(Up.Lf.)														
30 No. Teeth(Up.Rt.)					+									
31 No. Teeth(Low.Lf.)				--	-	+	+		++			-		++
32 No. Teeth(Low.Rt.)				-										++

^aBlanks indicate nonsignificant correlations. Individual symbols refer to significant positive or negative correlations ($P < 0.05$; greater than 0.456), double symbols indicate highly significant correlations ($P < 0.01$; greater than 0.575), and triple symbols represent very highly significant correlations ($P < 0.001$; greater than 0.693).

^bEnvironmental variables as numbered in Tables 2 and 12.

Table 14. Results of Mantel tests ($\underline{t}$) and matrix correlation ($\underline{r}$) for offshore Stenella attenuata. Comparison of interlocality differences for 14 environmental variables against those for tooth counts for 832 specimens in 20 blocks.

Environmental variable	<u>No. Teeth(Up.Lf.)</u>		<u>No. Teeth(Up.Rt.)</u>		<u>No. Teeth(Low.Lf.)</u>		<u>No. Teeth(Low.Rt.)</u>	
	$\underline{t}$	$\underline{r}$	$\underline{t}$	$\underline{r}$	$\underline{t}$	$\underline{r}$	$\underline{t}$	$\underline{r}$
1 Sea Current(N., Winter)	3.12**	.578	2.25*	.399	0.89	.118	2.66**	.441
2 Sea Current(W., Winter)	-0.98	-.152	0.01	.001	-0.00	-.000	-0.93	-.131
3 Water Depth	0.36	.059	0.73	.115	0.69	.083	1.39	.206
4 Solar Insolation(Jan.)	2.36*	.303	1.06	.111	3.06**	.274	2.66**	.268
5 Solar Insolation(Ann.)	2.37*	.255	2.98**	.353	1.82	.177	0.94	.106
6 Sea Surface Temp.(Jan.)	2.20*	.259	1.32	.151	2.43*	.230	2.24*	.243
7 Sea Surface Temp.(July)	2.09*	.262	1.23	.149	2.07*	.205	2.19*	.252
8 Sea Surface Temp.(Ann.Var.)	1.14	.155	-0.04	-.005	0.13	.014	0.68	.084
9 Oxygen Minimum Layer(Depth)	0.12	.014	-0.28	-.031	-0.89	-.082	-0.90	-.096
10 Oxygen Minimum Layer(Thick.)	3.13**	.339	4.08***	.430	4.13***	.371	2.86**	.289
11 Surface Salinity	0.20	.024	-0.98	-.133	1.36	.130	1.48	.163
12 Thermocline Depth(Winter)	0.14	.019	-0.35	-.044	-0.78	-.078	-0.22	-.026
13 Thermocline Depth(Summer)	-0.09	-.010	0.35	.036	3.55***	.317	1.68	.169
14 Thermocline Depth(Ann.Var.)	-0.27	-.033	0.26	.031	3.56***	.346	3.06**	.344

*, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$.

Table 15. Results of Mantel tests ($\underline{t}$) and matrix correlations ($\underline{r}$) for offshore Stenella attenuata. Comparison of interlocality differences for 14 environmental variables against those for projections onto the first two principal components based on 36 characters.

Environmental variable	Component			
	I		II	
	$\underline{t}$	$\underline{r}$	$\underline{t}$	$\underline{r}$
1 Sea Current(N.,Winter)	0.94	.153	-0.62	-.114
2 Sea Current(W.,Winter)	-0.16	-.021	0.61	.088
3 Water Depth	0.70	.094	-0.72	-.108
4 Solar Insolation(Jan.)	5.13***	.510	1.56	.166
5 Solar Insolation(Ann.)	2.60**	.288	1.35	.164
6 Sea Surface Temp.(Jan.)	2.93**	.296	2.66**	.289
7 Sea Surface Temp.(July)	3.47**	.384	1.42	.171
8 Sea Surface Temp.(Ann.Var.)	2.67**	.304	0.56	.070
9 Oxygen Minimum Layer(Depth)	-0.67	-.066	-1.27	-.134
10 Oxygen Minimum Layer(Thick.)	3.17**	.330	3.42***	.386
11 Surface Salinity	3.10**	.318	0.97	.107
12 Thermocline Depth(Winter)	1.29	.032	-0.41	-.050
13 Thermocline Depth(Summer)	2.37*	.227	2.86**	.292
14 Thermocline Depth(Ann.Var.)	-0.35	-.039	1.56	.192

*, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$.

Table 16. Results of Mantel tests ($\underline{t}$) and matrix correlations ($\underline{r}$) for offshore Stenella attenuata. Comparison of interlocality differences for 14 environmental variables against those for projections onto the first two canonical variables from a step-wise multiple discriminant analysis.

Environmental variable	Canonical variable			
	1		2	
	$\underline{t}$	$\underline{r}$	$\underline{t}$	$\underline{r}$
1 Sea Current(N.,Winter)	1.43	.162	-0.63	-.095
2 Sea Current(W.,Winter)	-1.23	-.121	2.69**	.327
3 Water Depth	1.39	.138	-0.58	-.072
4 Solar Insolation(Jan.)	9.57***	.814	-0.08	-.008
5 Solar Insolation(Ann.)	4.99***	.448	0.85	.090
6 Sea Surface Temp.(Jan.)	7.13***	.611	-1.42	-.138
7 Sea Surface Temp.(July)	7.59***	.680	-1.35	-.142
8 Sea Surface Temp.(Ann.Var.)	5.84***	.532	-1.07	-.116
9 Oxygen Minimum Layer(Depth)	-0.61	-.052	1.66	.158
10 Oxygen Minimum Layer(Thick.)	6.21***	.540	-0.39	-.039
11 Surface Salinity	5.96***	.514	-1.35	-.133
12 Thermocline Depth(Winter)	0.36	.032	0.43	.046
13 Thermocline Depth(Summer)	3.06**	.256	2.00*	.186
14 Thermocline Depth(Ann.Var.)	0.66	.059	1.36	.145

*, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$.

Table 17. Results of Mantel tests (t), matrix correlations (r), and product-moment correlations for body lengths of Stenella attenuata males (39 blocks) and females (47 blocks).

Environmental variable	Males			Females		
	Mantel		Product-moment correlation	Mantel		Product-moment correlation
	<u>t</u>	<u>r</u>		<u>t</u>	<u>r</u>	
1 Sea Current(N.,Winter)	4.76***	.696	-.506**	5.16***	.676	-.573***
2 Sea Current(W.,Winter)	-0.13	-.013	.104	-0.64	-.057	.041
3 Water Depth	2.02*	.222	-.321*	2.13*	.224	-.256
4 Solar Insolation(Jan.)	-0.21	-.020	-.177	0.00	-.001	-.187
5 Solar Insolation(Ann.)	-0.07	-.006	-.057	-0.58	-.039	-.032
6 Sea Surface Temp.(Jan.)	2.07*	.180	.283	1.59	.126	.295*
7 Sea Surface Temp.(July)	-0.57	-.065	.163	-0.01	-.009	.208
8 Sea Surface Temp.(Ann.Var.)	0.06	.007	-.177	0.86	.086	-.265
9 Oxygen Minimum Layer(Depth)	-1.22	-.100	-.094	-0.53	-.044	-.071
10 Oxygen Minimum Layer(Thick.)	-0.25	-.019	.052	-1.13	-.067	.109
11 Surface Salinity	1.91	.199	-.259	3.21**	.291	-.349*
12 Thermocline Depth(Winter)	0.32	.019	-.156	0.50	.027	-.148
14 Thermocline Depth(Ann.Var.)	0.13	.012	-.232	0.62	.066	-.073

*, P<0.05; **, P<0.01; ***, P<0.001.

Table 18(1/3). Sexual dimorphism in Stenella longirostris evaluated for 36 characters.

Character	F-value ^a	Mean ^b		Correction factor ^c	Percentage difference ^d
		Male	Female		
1 Condylobasal L.	0.28	402.82	403.96	-0.57	-0.28
2 L. Rostrum(frm.Base)	1.19	256.60	258.57	-0.98	-0.76
3 L. Rostrum(frm.Pterygoid)	0.50	298.12	299.49	-0.69	-0.46
4 W. Rostrum(at Base)	1.49	74.06	73.43	0.32	0.85
5 W. Rostrum(at 1/4 L.)	4.52*	52.72	51.73	0.50	1.90
6 W. Rostrum(at 1/2 L.)	4.62*	44.71	43.73	0.49	2.22
7 W. Premax.(at 1/2 L.)	4.17*	20.72	20.15	0.29	2.79
8 W. Rostrum(at 3/4 L.)	17.10***	33.31	31.42	0.94	5.84
9 Preorbital W.	5.17*	139.26	137.53	0.87	1.25
10 Postorbital W.	3.19	154.73	153.43	0.65	0.84
11 Skull W.(at Zygomatic P.)	6.57*	153.39	151.48	0.96	1.25
12 Skull W.(at Parietals)	7.78**	130.07	128.16	0.96	1.48
13 Ht. Braincase	6.90**	90.40	88.94	0.73	1.63
14 L. Braincase	4.46*	104.51	103.28	0.61	1.18
15 Max. W. Premax.	0.05	62.40	62.52	-0.06	-0.19
16 W. External Nares	0.02	40.21	40.16	0.02	0.12

Table 18(2/3). Sexual dimorphism in Stenella longirostris evaluated for 36 characters.

Character	F-value ^a	Mean ^b		Correction factor ^c	Percentage difference ^d
		Male	Female		
17 W. Lf. Premax.(md.Nares)	0.17	23.85	23.75	0.05	0.42
18 W. Rt. Premax.(md.Nares)	0.05	37.46	37.38	0.04	0.21
19 L. Temporal Fossa	7.23**	48.51	46.99	0.76	3.18
20 W. Temporal Fossa	15.82**	36.90	35.07	0.92	5.09
21 Orbital L.	0.26	39.95	40.10	-0.07	-0.37
22 L. Antorbital P.	9.92**	42.86	41.54	0.66	3.13
23 Sep. Pterygoids	1.76	1.68	1.50	0.09	11.32
24 W. Internal Nares	2.42	43.05	42.52	0.27	1.24
25 L. Lf. Tympanic Cavity	0.46	46.09	45.80	0.15	0.63
26 L. Rt. Tympanic Cavity	0.07	46.12	46.01	0.06	0.24
27 W. at Pterygo. Sutures	0.86	43.24	42.84	0.20	0.93
28 L. Up. Toothrow	2.49	220.60	223.09	-1.24	-1.12
29 No. Teeth(Up.Lf.)	0.31	53.35	53.10	0.12	0.47
30 No. Teeth(Up.Rt.)	0.00	53.06	53.04	0.01	0.04
31 No. Teeth(Low.Lf.)	0.06	51.28	51.38	-0.05	-0.19
32 No. Teeth(Low.Rt.)	0.50	50.93	51.22	-0.14	-0.57

Table 18(3/3). Sexual dimorphism in *Stenella longirostris* evaluated for 36 characters.

Character	F-value ^a	Mean ^b		Correction factor ^c	Percentage difference ^d
		Male	Female		
33 L. Low. Toothrow	1.40	215.37	217.25	-0.94	-0.87
34 Ht. Ramus	5.63*	55.07	54.23	0.42	1.54
35 Tooth W.	2.67	2.77	2.71	0.03	2.19
36 L. Ramus	0.10	344.09	344.73	-0.32	-0.19

^aF-value from two-way analysis of variance(sex vs. 5^o block) involving 11 blocks (*, P<0.05;** , P<0.01;***, P<0.001).

^bUnweighted mean for the 11 blocks.

^cAdded to all individual female measurements and subtracted from all individual male measurements to correct for sexual differences.

^d The difference between sexes multiplied by 100, with the resulting value divided by the average of the male and female means.

Table 19(1/2). Principal component loadings for Stenella longirostris involving character means for 20 blocks.

Character	Component			
	I	II	III	IV
1 Condylbasal L.	.933	-.282	.004	-.102
2 L. Rostrum(frm.Base)	.872	-.409	.021	-.109
3 L. Rostrum(frm.Pterygoid)	.884	-.407	-.061	-.142
4 W. Rostrum(at Base)	.907	.182	.009	-.054
5 W. Rostrum(at 1/4 L.)	.816	.284	-.013	.154
6 W. Rostrum(at 1/2 L.)	.850	.207	-.030	.220
7 W. Premax.(at 1/2 L.)	.587	.092	.569	.062
8 W. Rostrum(at 3/4 L.)	.469	.456	.238	.357
9 Preorbital W.	.918	.241	-.133	.053
10 Postorbital W.	.943	.199	-.152	.059
11 Skull W.(at Zygomatic P.)	.952	.216	-.112	.046
12 Skull W.(at Parietals)	.763	.101	-.037	.278
13 Ht. Braincase	.835	.352	-.172	.144
14 L. Braincase	.860	.301	-.001	-.107
15 Max. W. Premax.	.661	-.254	.127	-.610
16 W. External Nares	.645	.027	.457	-.058
17 W. Lf. Premax.(md.Nares)	.766	-.170	-.233	-.393
18 W. Rt. Premax.(md.Nares)	.842	-.123	.142	-.381
19 L. Temporal Fossa	.788	.158	.032	.110
20 W. Temporal Fossa	.557	.592	-.204	.281
21 Orbital L.	.587	.149	-.364	-.106
22 L. Antorbital P.	.792	.022	-.214	.227
23 Sep. Pterygoids	-.012	.195	-.842	.103

Table 19(2/2). Principal component loadings for Stenella longirostris involving character means for 20 blocks.

Character	Component			
	I	II	III	IV
24 W. Internal Nares	.867	.223	-.244	.093
25 L. Lf. Tympanic Cavity	.614	.324	.590	.131
26 L. Rt. Tympanic Cavity	.666	.320	.519	.201
27 W. at Pterygo. Sutures	.920	.044	-.049	-.058
28 L. Up. Toothrow	.832	-.505	.002	-.134
29 No. Teeth(Up.Lf.)	.310	-.766	.138	.332
30 No. Teeth(Up.Rt.)	.416	-.801	.091	.262
31 No. Teeth(Low.Lf.)	.308	-.792	-.199	.386
32 No. Teeth(Low.Rt.)	.386	-.756	-.222	.401
33 L. Low. Toothrow	.773	-.581	-.063	-.115
34 Ht. Ramus	.878	.159	.104	-.120
35 Tooth W.	.474	.466	-.353	-.288
36 L. Ramus	.893	-.345	.045	-.136

Table 20. Step-wise discriminant analysis of all specimens from 20 blocks for Stenella longirostris.

Character	F-value to enter	Order of entry	Coefficients ^a	
			1	2
8 W. Rostrum(at 3/4 L.)	2.99	2	0.1040	0.1179
10 Postorbital W.	18.80	1	-0.1692	0.1413
14 L. Braincase	1.65	7	0.2945	-0.1141
15 Max. W. Premax.	1.57	8	-0.3801	-0.0335
18 W. Rt. Premax.(md.Nares)	2.19	9	-0.0807	0.0623
24 W. Internal Nares	2.26	4	-0.1813	0.1501
27 W. at Pterygo. Sutures	2.16	5	-0.0166	-0.3074
33 L. Low. Toothrow	2.73	3	-0.0052	-0.0790
35 Tooth W.	1.79	6	-0.0522	0.5771
Constant			36.2289	-1.4577

^aFor canonical variable.

Table 21(1/2). Association of interlocality character differences with geographic distances (in nautical miles) and the reciprocals of these distances. Results from Mantel tests and matrix correlations for Stenella longirostris.

Character	Distance		Reciprocal of distance	
	<u>t</u>	<u>r</u>	<u>t</u>	<u>r</u>
1 Condylobasal L.	2.95**	.298	-3.32***	-.282
2 L. Rostrum(frm.Base)	2.05*	.224	-2.73**	-.243
3 L. Rostrum(frm.Pterygoid)	2.12*	.229	-2.57**	-.226
4 W. Rostrum(at Base)	3.38***	.300	-4.35***	-.346
5 W. Rostrum(at 1/4 L.)	2.63**	.205	-2.44*	-.182
6 W. Rostrum(at 1/2 L.)	2.90**	.256	-2.80	-.221
7 W. Premax.(at 1/2 L.)	-0.14	-.012	-0.12	-.010
8 W. Rostrum(at 3/4 L.)	2.03*	.232	-1.56	-.142
9 Preorbital W.	4.95***	.372	-5.29***	-.389
10 Postorbital W.	4.97***	.404	-5.06***	-.385
11 Skull W.(at Zygomatic P.)	5.06***	.407	-5.19***	-.393
12 Skull W.(at Parietals)	2.24*	.244	-1.96*	-.174
13 Ht. Braincase	2.31*	.222	-3.06**	-.253
14 L. Braincase	3.14**	.305	-3.79***	-.315
15 Max. W. Premax.	1.43	.144	-2.75**	-.234
16 W. External Nares	5.06***	.407	-5.18***	-.393
17 W. Lf. Premax.(md.Nares)	3.43***	.301	-3.72***	-.295
18 W. Rt. Premax.(md.Nares)	2.31*	.205	-3.72***	-.296
19 L. Temporal Fossa	2.28*	.271	-2.39*	-.224
20 W. Temporal Fossa	2.48*	.253	-2.83**	-.242
21 Orbital L.	2.68**	.261	-2.66**	-.221

Table 21(2/2). Association of interlocality character differences with geographic distances (in nautical miles) and the reciprocals of these distances. Results from Mantel tests and matrix correlations for Stenella longirostris.

Character	Distance		Reciprocal of distance	
	<u>t</u>	<u>r</u>	<u>t</u>	<u>r</u>
22 L. Antorbital P.	2.64**	.256	-2.69**	-.223
23 Sep. Pterygoids	0.08	.010	-0.65	-.067
24 W. Internal Nares	4.33***	.374	-4.56***	-.358
25 L. Lf. Tympanic Cavity	2.92**	.300	-3.40***	-.292
26 L. Rt. Tympanic Cavity	1.63	.168	-2.05*	-.177
27 W. at Pterygo. Sutures	4.23***	.381	-4.30***	-.344
28 L. Up. Toothrow	1.74	.192	-2.35*	-.210
29 No. Teeth(Up.Lf.)	0.05	.005	-0.68	-.063
30 No. Teeth(Up.Rt.)	0.01	.001	-1.09	-.104
31 No. Teeth(Low.Lf.)	-0.69	-.091	0.11	.011
32 No. Teeth(Low.Rt.)	-0.99	-.128	0.34	.034
33 L. Low. Toothrow	0.89	.105	-1.58	-.147
34 Ht. Ramus	5.02***	.473	-4.10***	-.336
35 Tooth W.	2.06*	.234	-2.19*	-.199
36 L. Ramus	2.43*	.254	-3.03**	-.263
Component I	3.85***	.335	-4.17***	-.328
Component II	0.01	.001	-0.45	-.045
Component III	-0.19	-.025	-0.03	-.003
Component IV	1.42	.167	-1.79	-.166
Canonical Variable 1	4.78***	.396	-2.93**	-.187
Canonical Variable 2	-0.59	-.081	-0.43	-.018

*, P<0.05; **, P<0.01; ***, P<0.001.

Table 22. Association of interlocality character differences with geographic distances (in nautical miles) and the reciprocals of these distances. Results from Mantel tests and matrix correlations for 242 specimens from 22 blocks for Stenella longirostris.

Character		Distance		Reciprocal of distance	
		<u>t</u>	<u>r</u>	<u>t</u>	<u>r</u>
29	No. Teeth(Up.Lf.)	0.21	.024	-0.50	-.046
30	No. Teeth(Up.Rt.)	0.00	.000	-0.49	-.045
31	No. Teeth(Low.Lf.)	-0.78	-.098	0.02	.002
32	No. Teeth(Low.Rt.)	-0.98	-.098	0.10	.002

*, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$.

Table 23(1/3). Product-moment correlations of block means for morphological and environmental variables based on 20 blocks of Stenella longirostris.^a

Character	Environmental variable ^b													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1 Condylbasal L.				++			--	++			+			
2 L. Rostrum(frm.Base)				+			--	+			+			
3 L. Rostrum(frm.Pterygoid)				+			--	++			+			
4 W. Rostrum(at Base)				+++		--	--	++			+++			
5 W. Rostrum(at 1/4 L.)				+++	+		--	+		-	+			
6 W. Rostrum(at 1/2 L.)				++	+		--			-	+			
7 W. Premax.(at 1/2 L.)														
8 W. Rostrum(at 3/4 L.)														
9 Preorbital W.				+++		--	--	+++		--	+++			
10 Postorbital W.				+++		--	--	+++		--	+++			
11 Skull W.(at Zygomatic P.)				+++		--	--	+++		-	+++			
12 Skull W.(at Parietals)				+		--	--	+++		+	++			
13 Ht. Braincase			+	++			-			-	+			
14 L. Braincase				+++		--	--	++		--	+++			
15 Max. W. Premax.			++	+++		--	--	+++		-	+++			

Table 23(3/3). Product-moment correlations of block means for morphological and environmental variables based on 20 blocks of Stenella longirostris.^a

Character	Environmental variable ^b													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
31 No. Teeth(Low.Lf.)														
32 No. Teeth(Low.Rt.)														
33 L. Low. Toothrow							-	+						
34 Ht. Ramus	+			+++		-	---	++		+				
35 Tooth W.			+	++			---	+						
36 L. Ramus				+			---	+		+				
Component I				+++		-	---	++		-	++	-		
Component II			+											
Component III		-												
Component IV					+									
Canonical Variable 1				---		++	+++	---	+	++	---	+		
Canonical Variable 2														

^a Blanks indicate nonsignificant correlations. Individual symbols refer to significant positive or negative correlations ($P < 0.05$; greater than 0.444), double symbols indicate highly significant correlations ($P < 0.01$; greater than 0.561), and triple symbols represent very highly significant correlations ($P < 0.001$; greater than 0.679).

^b Environmental variables as numbered in Tables 2 and 24.

Table 24. Results of Mantel tests(t) and matrix correlations (r) for *Stenella longirostris*. Comparison of interlocality differences for 14 environmental variables against those for the first five morphological variables entered into a step-wise multiple discriminant analysis.

Environmental variable	Postorbital W.		W. Rostrum(at 3/4 L.)		L. Low. Toothrow W.		Internal Nares W.		at Pterygo. Sutures	
	t	r	t	r	t	r	t	r	t	r
1 Sea Current(N., Winter)	-0.21	-.020	1.22	.199	0.76	.129	1.79	.190	1.18	.135
2 Sea Current(W., Winter)	-1.82	-.152	0.97	.119	-1.78	-.226	-0.84	-.075	-1.65	-.155
3 Water Depth	0.70	.062	0.24	.034	1.57	.226	1.25	.120	0.74	.075
4 Solar Insolation(Jan.)	7.28***	.604	0.55	.067	0.22	.027	6.49***	.577	5.03***	.470
5 Solar Insolation(Ann.)	0.35	.031	1.16	.174	-1.16	-.180	2.96**	.296	0.88	.094
6 Sea Surface Temp.(Jan.)	5.48***	.427	0.36	.036	1.00	.101	4.95***	.401	3.59***	.300
7 Sea Surface Temp.(July)	9.23***	.736	-0.75	-.081	1.70	.189	5.79***	.487	5.78***	.504
8 Sea Surface Temp.(Ann.Var.)	6.26***	.478	-0.04	-.004	2.45*	.230	3.88***	.305	4.33***	.348
9 Oxygen Minimum Layer(Depth)	0.89	.072	0.29	.003	0.71	.082	0.27	.023	0.40	.036
10 Oxygen Minimum Layer(Thick.)	2.93**	.233	-0.11	-.012	-1.29	-.143	3.69***	.310	1.92	.167
11 Surface Salinity	7.08***	.521	-1.26	-.098	3.60***	.281	4.50***	.334	3.48***	.260
12 Thermocline Depth(Winter)	2.45*	.184	1.62	.178	1.07	.121	-1.01	-.087	3.97***	.351
13 Thermocline Depth(Summer)	0.31	.024	-0.45	-.046	0.30	.031	0.12	.010	-0.81	-.069
14 Thermocline Depth(Ann.Var.)	-0.37	-.031	0.05	.007	0.32	.042	-0.45	-.041	-0.27	-.026

*, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$.

Table 25. Results of Mantel tests(t) and matrix correlations (r) for Stenella longirostris. Comparison of interlocality differences for 14 environmental variables against those for tooth counts based on 242 specimens in 22 blocks.

Environmental variable	No. Teeth(Up.Lf.)		No. Teeth(Up.Rt.)		No. Teeth(Low.Lf.)		No. Teeth(Low.Rt.)	
	<u>t</u>	<u>r</u>	<u>t</u>	<u>r</u>	<u>t</u>	<u>r</u>	<u>t</u>	<u>r</u>
1 Sea Current(N., Winter)	2.33*	.393	2.38*	.412	1.30	.238	0.95	.172
2 Sea Current(W., Winter)	-0.40	-.049	-0.66	-.083	-0.04	-.006	0.24	.031
3 Water Depth	3.11**	.404	3.58***	.475	2.02*	.282	1.38	.191
4 Solar Insolation(Jan.)	1.56	.190	1.63	.203	-1.11	-.146	-1.60	-.207
5 Solar Insolation(Ann.)	2.87**	.424	2.68**	.405	-0.04	-.006	-0.31	-.049
6 Sea Surface Temp.(Jan.)	1.43	.145	1.65	.170	0.25	.026	-0.32	-.034
7 Sea Surface Temp.(July)	-1.29	-.146	-0.99	-.115	-1.24	-.151	-1.41	-.169
8 Sea Surface Temp.(Ann.Var.)	-0.75	-.076	-0.49	-.051	-0.82	-.088	-1.32	-.140
9 Oxygen Minimum Layer(Depth)	-1.43	-.168	0.94	.094	-1.17	-.147	-0.94	-.116
10 Oxygen Minimum Layer(Thick.)	1.21	.119	-0.92	-.110	0.77	.080	0.92	.094
11 Surface Salinity	-0.30	-.025	0.42	.036	1.08	.094	0.89	.077
12 Thermocline Depth(Winter)	-0.05	-.006	-0.34	-.043	0.02	.002	-0.20	-.025
13 Thermocline Depth(Summer)	0.17	.019	-0.27	-.030	0.77	.090	0.96	.109
14 Thermocline Depth(Ann.Var.)	0.24	.031	0.08	.010	0.95	.129	0.94	.126

*, P<0.05; **, P<0.01; ***, P<0.001.

Table 26. Results of Mantel tests (t) and matrix correlations (r) for Stenella longirostris. Comparison of interlocality differences for 14 environmental variables against those for projections onto the first four principal components based on 36 characters.

	Environmental variable	Component							
		I		II		III		IV	
		<u>t</u>	<u>r</u>	<u>t</u>	<u>r</u>	<u>t</u>	<u>r</u>	<u>t</u>	<u>r</u>
1	Sea Current(N.,Winter)	-0.27	-.029	2.15*	.410	-0.37	-.072	-0.32	-.053
2	Sea Current(W.,Winter)	-2.38*	-.215	-0.49	-.068	1.40	.196	2.05*	.260
3	Water Depth	0.55	.054	2.95**	.476	-0.71	-.115	-0.55	-.079
4	Solar Insolation(Jan.)	5.19***	.465	0.42	.058	-0.15	-.021	-0.56	-.070
5	Solar Insolation(Ann.)	-0.23	-.023	1.13	.197	0.79	.138	0.67	.104
6	Sea Surface Temp.(Jan.)	3.41***	.278	1.22	.134	-0.49	-.054	-1.20	-.122
7	Sea Surface Temp.(July)	6.48***	.548	-1.19	-.144	0.02	.002	-0.91	-.101
8	Sea Surface Temp.(Ann.Var.)	4.81***	.380	-0.83	-.083	0.06	.006	-0.61	-.057
9	Oxygen Minimum Layer(Depth)	0.45	.039	-0.56	-.073	-0.88	-.113	-0.26	-.030
10	Oxygen Minimum Layer(Thick.)	1.32	.111	-0.00	-.000	1.64	.198	2.25*	.249
11	Surface Salinity	5.45***	.404	0.73	.058	-0.93	-.074	-0.71	-.056
12	Thermocline Depth(Winter)	3.97***	.351	-0.43	-.054	0.10	.012	-0.62	-.070
13	Thermocline Depth(Summer)	0.30	.025	0.99	.110	-0.05	-.006	1.38	.142
14	Thermocline Depth(Ann.Var.)	-0.86	-.079	1.02	.148	-1.27	-.185	0.42	.054

*, P<0.05; **, P<0.01; ***, P<0.001.

Table 27. Results of Mantel tests (t) and matrix correlations (r) for Stenella longirostris. Comparison of interlocality differences for 14 environmental variables against those for projections onto the first two canonical variables from a step-wise multiple discriminant analysis.

Environmental variable	Canonical variable			
	1		2	
	<u>t</u>	<u>r</u>	<u>t</u>	<u>r</u>
1 Sea Current(N., Winter)	-0.40	-.040	1.62	.334
2 Sea Current(W., Winter)	-1.54	-.131	-0.08	-.012
3 Water Depth	0.62	.056	2.41*	.417
4 Solar Insolation(Jan.)	7.11***	.602	0.10	.014
5 Solar Insolation(Ann.)	0.45	.042	0.85	.159
6 Sea Surface Temp.(Jan.)	6.06***	.479	0.67	.077
7 Sea Surface Temp.(July)	9.24***	.749	-0.99	-.126
8 Sea Surface Temp.(Ann.Var.)	6.64***	.512	-0.87	-.090
9 Oxygen Minimum Layer(Depth)	1.66	.137	-0.77	-.104
10 Oxygen Minimum Layer(Thick.)	3.24**	.263	0.57	.073
11 Surface Salinity	7.39***	.546	0.76	.062
12 Thermocline Depth(Winter)	1.82	.149	-0.73	-.096
13 Thermocline Depth(Summer)	0.01	.001	0.50	.058
14 Thermocline Depth(Ann.Var.)	-0.96	-.083	1.14	.177

*, P<0.05; **, P<0.01; ***, P<0.001.

Table 28. Results of Mantel tests (t), matrix correlations (r), and product-moment correlations for body lengths of Stenella longirostris males (35 blocks) and females (37 blocks).

Environmental variable	Males			Females		
	Mantel		Product-moment correlation	Mantel		Product-moment correlation
	<u>t</u>	<u>r</u>		<u>t</u>	<u>r</u>	
1 Sea Current(N.,Winter)	1.55	.206	-.170	0.43	.042	.215
2 Sea Current(W.,Winter)	0.05	.004	.273	1.88	.113	.105
3 Water Depth	4.59***	.665	.169	0.92	.071	.019
4 Solar Insolation(Jan.)	4.38***	.411	.643***	3.37***	.232	.579***
5 Solar Insolation(Ann.)	-0.17	-.014	.079	3.74***	.235	.580***
6 Sea Surface Temp.(Jan.)	3.21**	.247	-.595***	1.51	.093	-.431**
7 Sea Surface Temp.(July)	4.71***	.487	-.681***	3.02**	.247	-.540***
8 Sea Surface Temp.(Ann.Var.)	4.08***	.417	.631***	2.19*	.184	.381*
9 Oxygen Minimum Layer(Depth)	3.98***	.361	-.510**	-1.35	-.072	.068
10 Oxygen Minimum Layer(Thick.)	0.46	.038	-.388*	7.52***	.437	-.690***
11 Surface Salinity	4.05***	.406	.652***	2.49*	.193	.563***
12 Thermocline Depth(Winter)	-0.76	-.042	-.250	0.23	.011	-.047
14 Thermocline Depth(Ann.Var.)	-0.24	-.025	-.255	0.68	.047	-.182

*, P<0.05; **, P<0.01; ***, P<0.001.

Table 29. Comparisons of principal component projections for offshore Stenella attenuata and S. longirostris based on corresponding data for 13 blocks. Product-moment correlations (above), t-values for Mantel test, and matrix correlations (below) are given.

<u>S. longirostris</u> component	<u>S. attenuata</u> component	
	I	II
I	.799**	.177
	4.16***	-0.68
	.556	-.097
II	.338	-.432
	-0.29	1.59
	-.043	.264
III	.200	-.198
	0.10	0.25
	.020	.055
IV	.117	.426
	0.23	2.38*
	.040	.493

*, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$.

Table 30. Comparisons of canonical variable projections for offshore Stenella attenuata and S. longirostris based on corresponding data for 13 blocks. Product-moment correlations (above), t-values for Mantel test, and matrix correlations (below) are given.

<u>S. longirostris</u> variable	<u>S. attenuata</u> variable	
	1	2
1	.942***	-.223
	6.99***	-0.65
	.858	-.071
2	-.114	-.082
	0.80	-0.70
	.101	-.076

*, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$.

Table 31(1/2). Results of Mantel tests (t), matrix correlations (r) and product-moment correlations for 13 overlapping blocks of Stenella attenuata and S. longirostris. Comparison of interlocality differences for 36 morphological variables.

Character	Mantel		Product-moment correlation
	<u>t</u>	<u>r</u>	
1 Condylbasal L.	-0.51	-.097	.376
2 L. Rostrum(frm.Base)	-0.50	-.094	.267
3 L. Rostrum(frm.Pterygoid)	-0.64	-.125	.354
4 W. Rostrum(at Base)	4.56***	.589	.813***
5 W. Rostrum(at 1/4 L.)	2.10*	.213	.615*
6 W. Rostrum(at 1/2 L.)	4.42***	.475	.780**
7 W. Premax.(at 1/2 L.)	2.36*	.303	.604*
8 W. Rostrum(at 3/4 L.)	0.34	.064	.448
9 Preorbital W.	5.62***	.734	.872***
10 Postorbital W.	4.46***	.627	.820***
11 Skull W.(at Zygomatic P.)	4.90***	.656	.838***
12 Skull W.(at Parietals)	-0.57	-.106	-.024
13 Ht. Braincase	-0.71	-.106	-.052
14 L. Braincase	-0.71	-.104	-.257
15 Max. W. Premax.	3.46***	.520	.766**
16 W. External Nares	-0.48	-.094	.318
17 W. Lf. Premax.(md.Nares)	0.91	.118	.445
18 W. Rt. Premax.(md.Nares)	4.30***	.660	.827***
19 L. Temporal Fossa	1.40	.167	-.618*
20 W. Temporal Fossa	2.78**	.353	-.687**
21 Orbital L.	0.14	.019	.287

Table 31(2/2). Results of Mantel tests (t), matrix correlations (r) and product moment correlations for 13 overlapping blocks of Stenella attenuata and S. longirostris. Comparison of interlocality differences for 36 morphological variables.

Character	Mantel		Product-moment correlation
	<u>t</u>	<u>r</u>	
22 L. Antorbital P.	2.40*	.310	.639*
23 Sep. Pterygoids	-0.15	-.038	.231
24 W. Internal Nares	1.39	.199	.224
25 L. Lf. Tympanic Cavity	0.33	.059	.148
26 L. Rt. Tympanic Cavity	-0.58	-.057	.136
27 W. at Pterygo. Sutures	0.25	.036	.097
28 L. Up. Toothrow	-1.44	-.267	-.029
29 No. Teeth(Up.Lf.)	0.70	.141	-.527
30 No. Teeth(Up.Rt.)	6.44*	.982	-.657*
31 No. Teeth(Low.Lf.)	1.95	.286	-.479
32 No. Teeth(Low.Rt.)	0.57	.085	-.349
33 L. Low. Toothrow	-1.13	-.206	-.110
34 Ht. Ramus	-1.24	-.233	.008
35 Tooth W.	-0.06	-.014	.376
36 L. Ramus	-0.77	-.138	.346

*, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$.

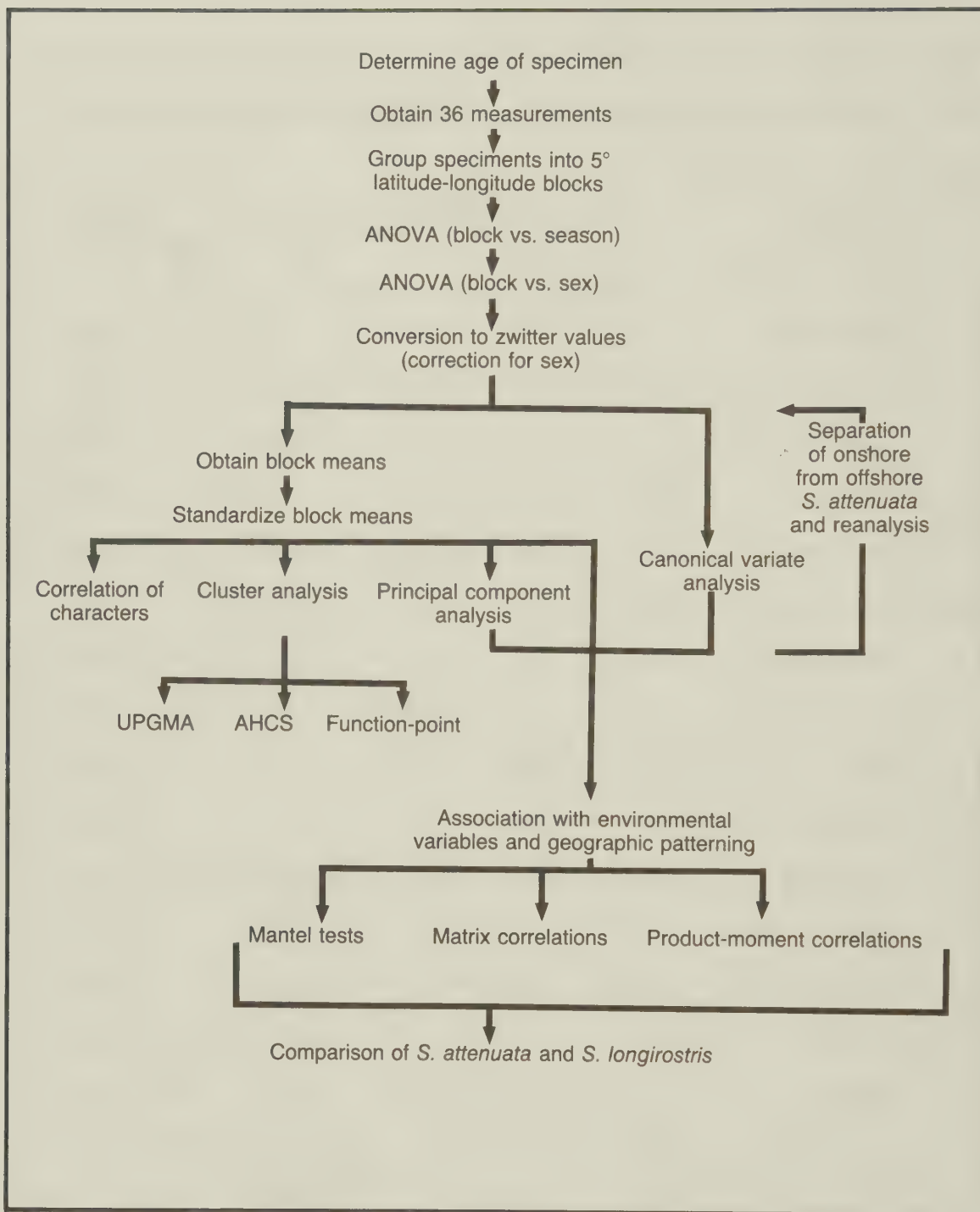
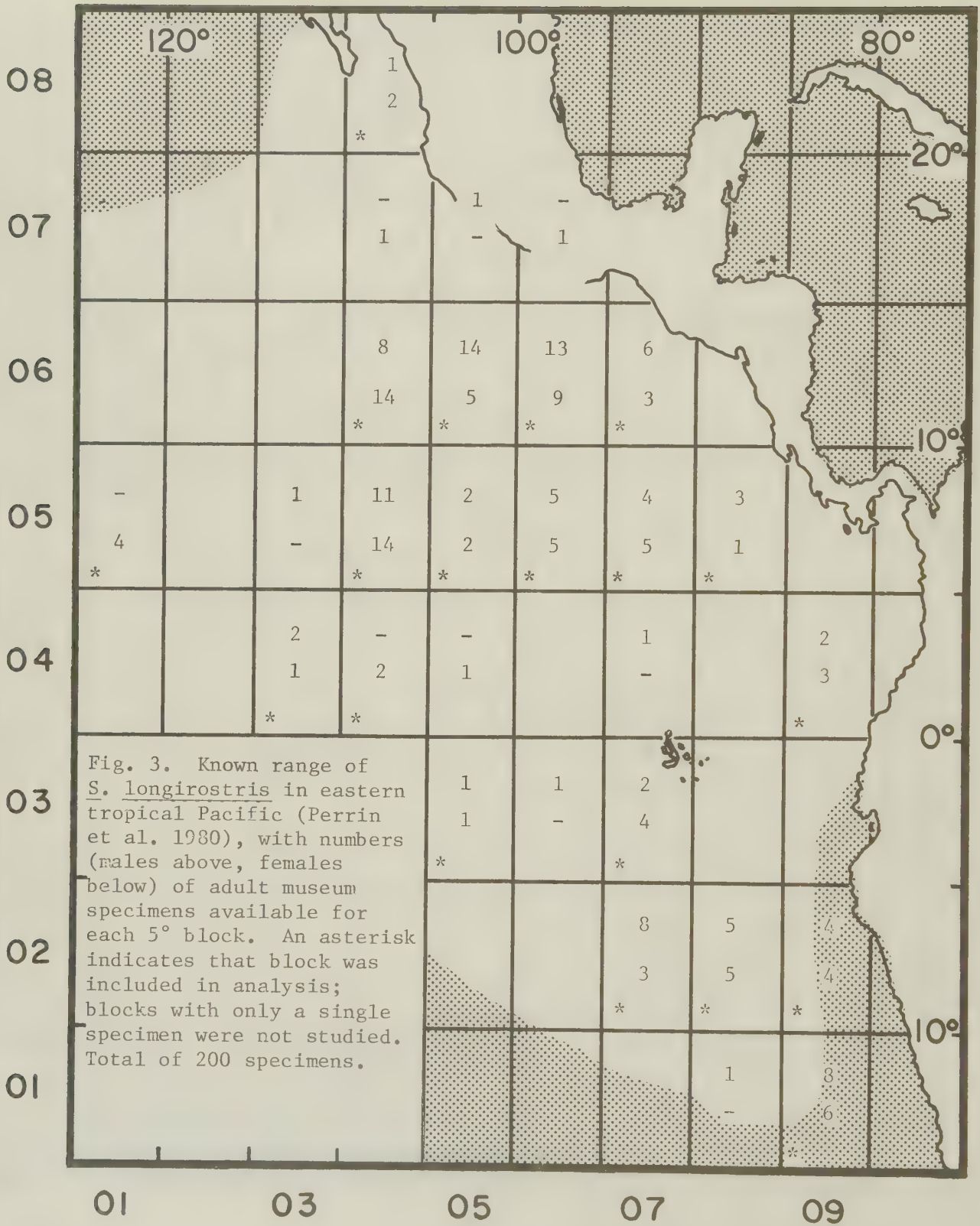


Fig. 1. Flow diagram indicating statistical analyses performed using 36 morphological characters from skulls of *Stenella attenuata* and *S. longirostris*.



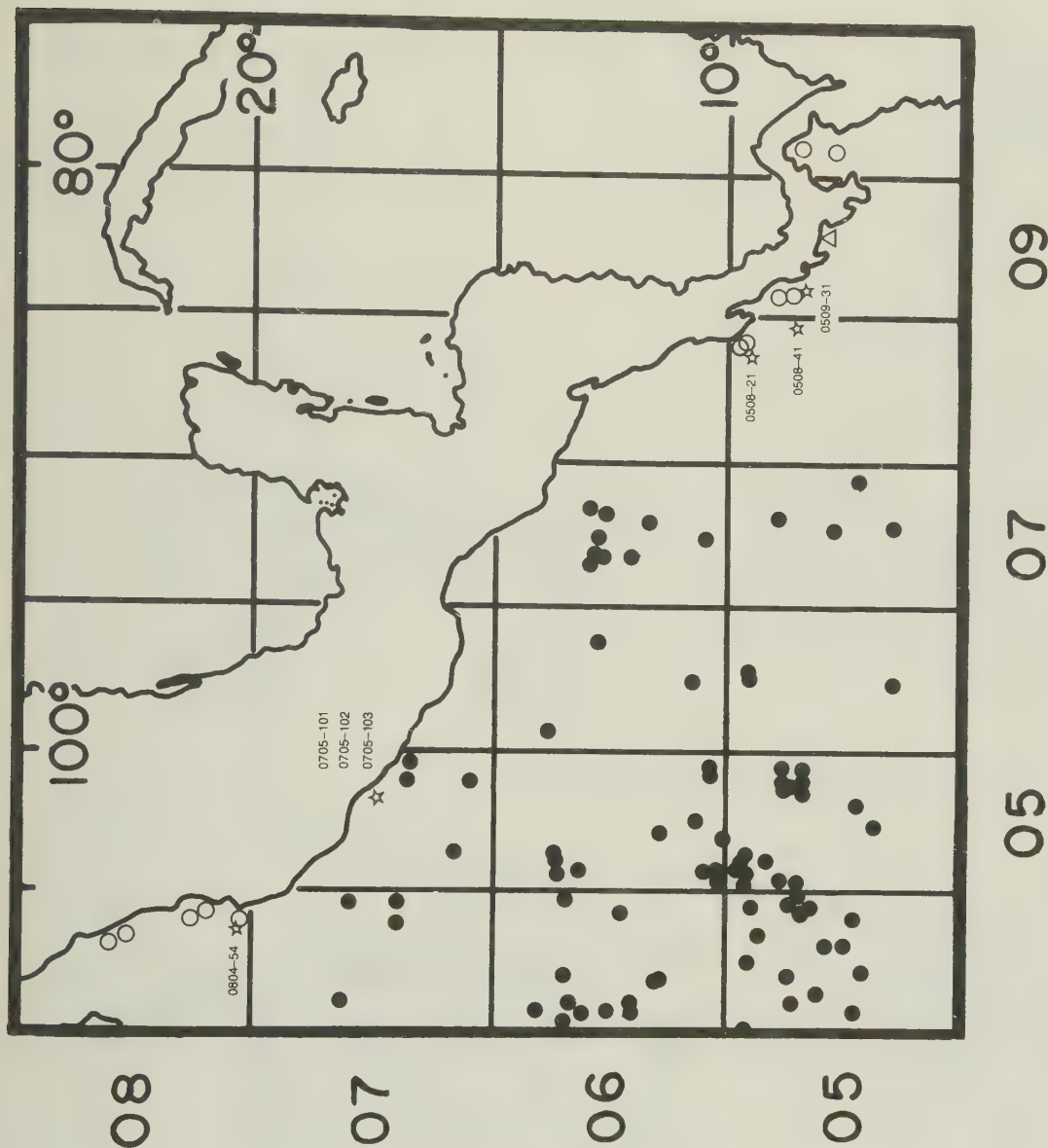


Fig. 4. Specific collecting localities for onshore (open circles) and offshore (darkened circles) *Stenella attenuata* from blocks in the northeastern portion of our study region. Circles often represent more than one specimen. The open triangle indicates the locality for the holotype of *S. attenuata graffmani*. Locations of the following "unknown" specimens are represented by stars: 0508-21, Museum number NMNH 395938; 0508-41, NMNH 487417; 0509-31, NMNH 487610; 0705-101, NMNH 395926; 0705-102, NMNH 395927; 0705-103, NMNH 395928; 0804-54, SWFC DJT045.

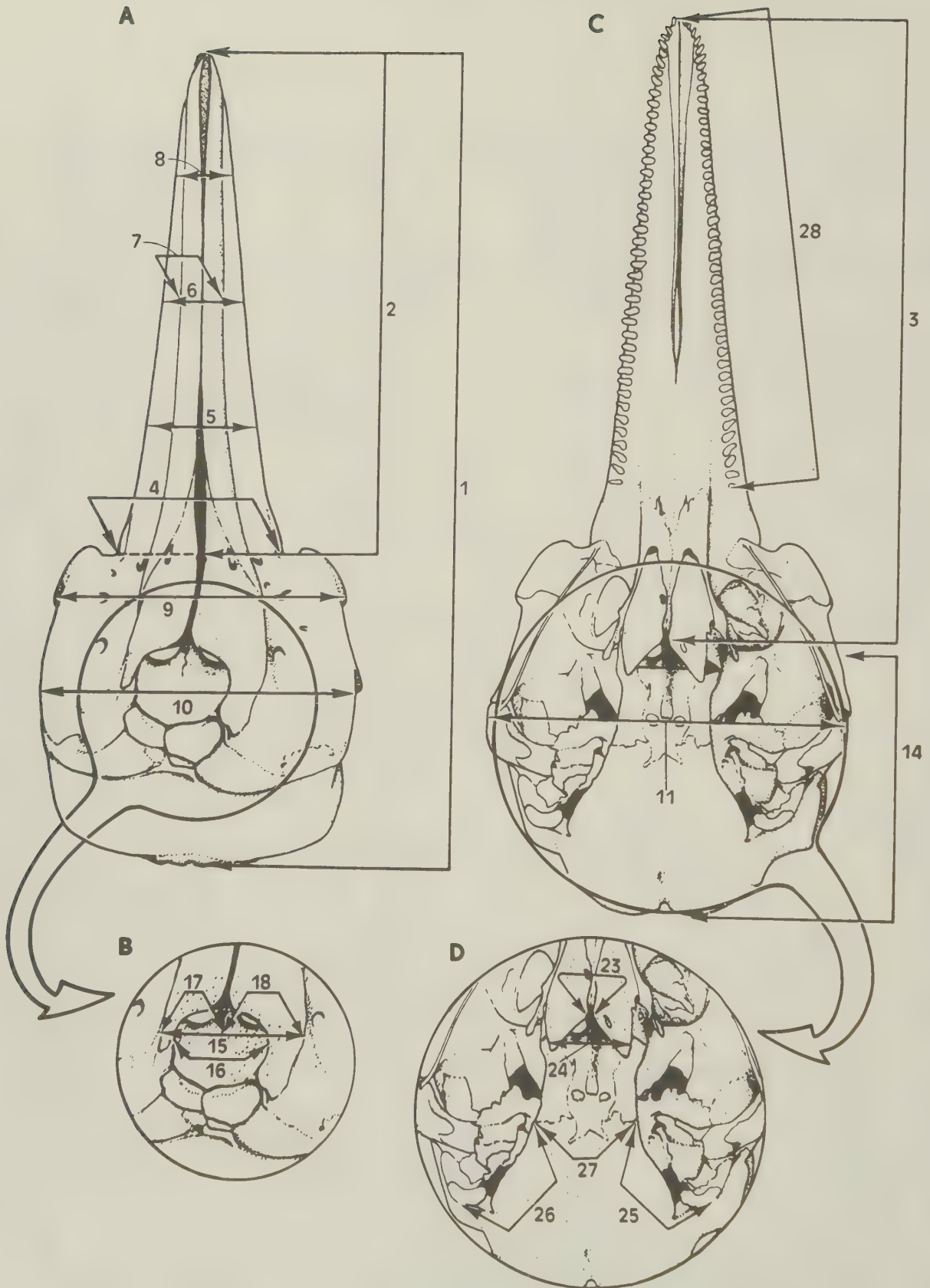


Fig. 5(1/2). Skull and mandibular measurements. Numbers refer to descriptions in Table 1.

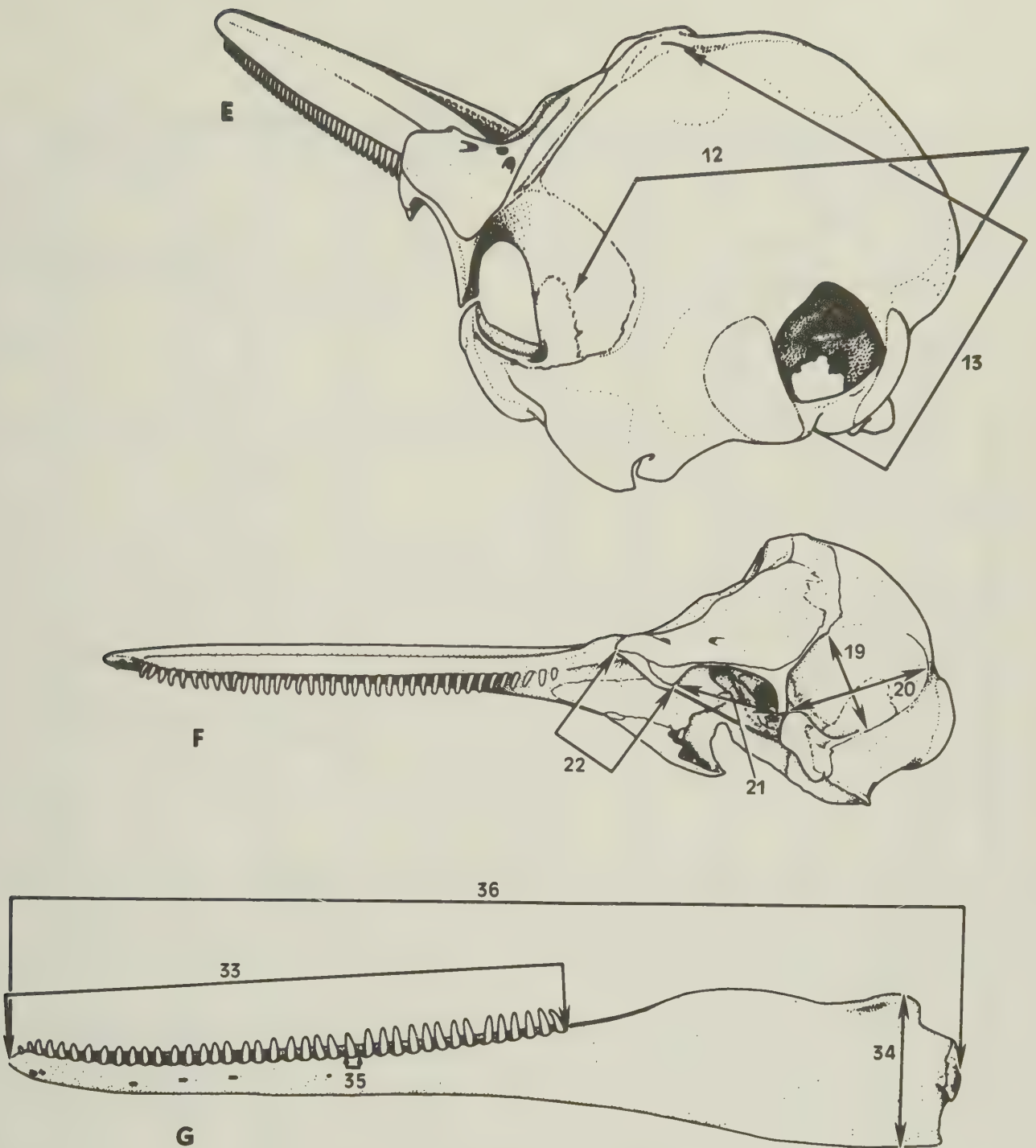
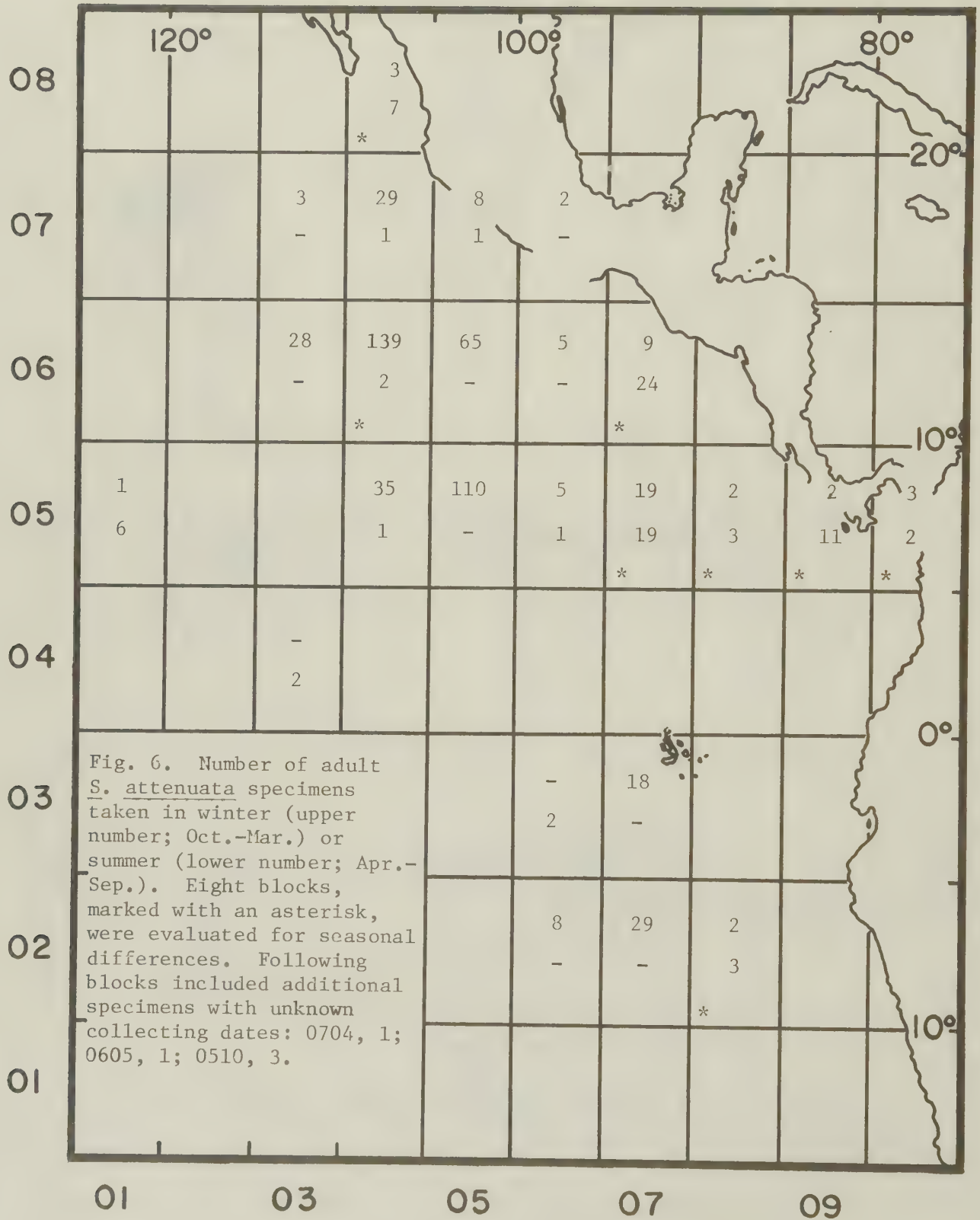


Fig. 5(2/2). Skull and mandibular measurements. Numbers refer to descriptions in Table 1.



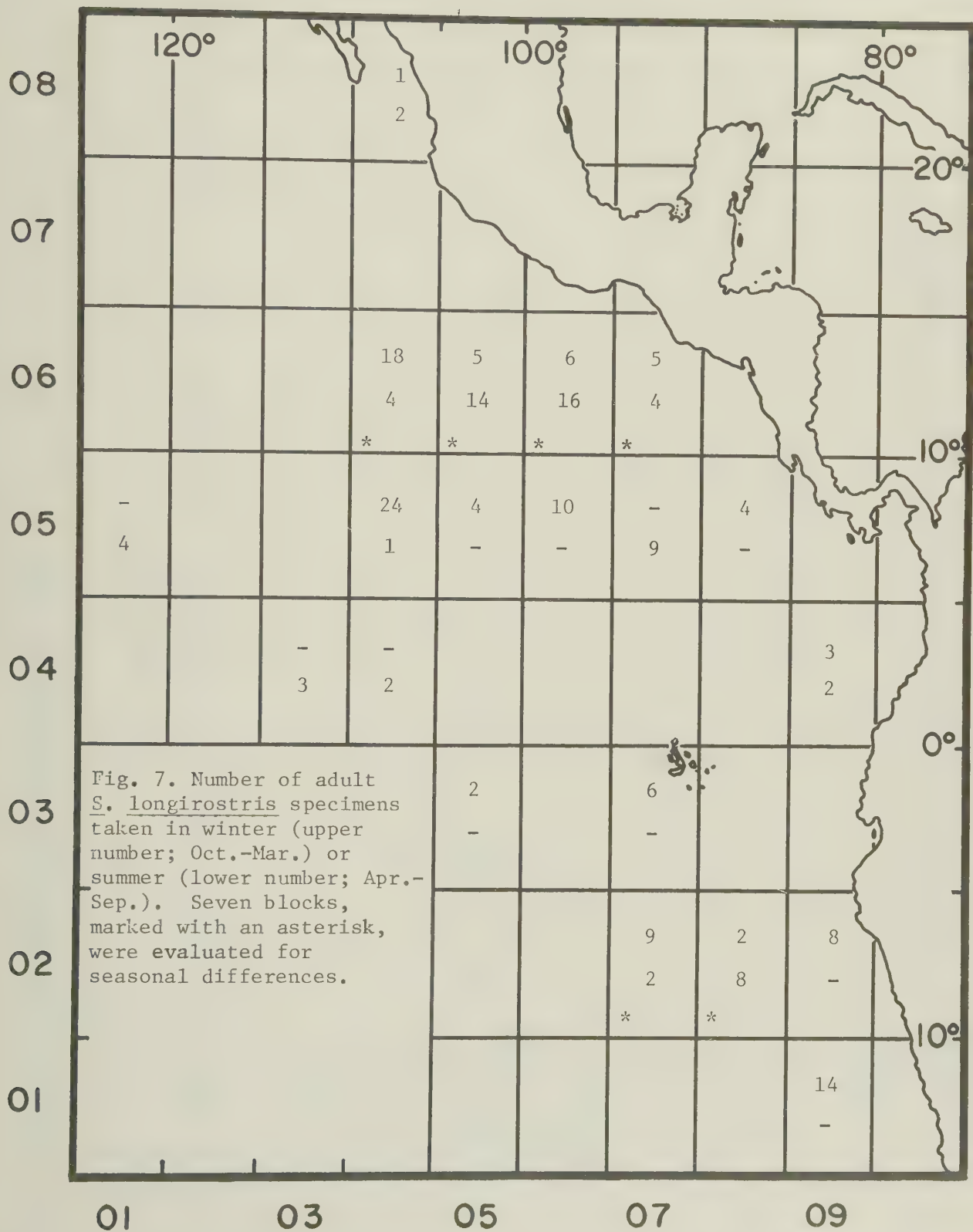




Fig. 8. Projections of 23 blocks onto the first two principal components based on 36 characters for Stenella attenuata.

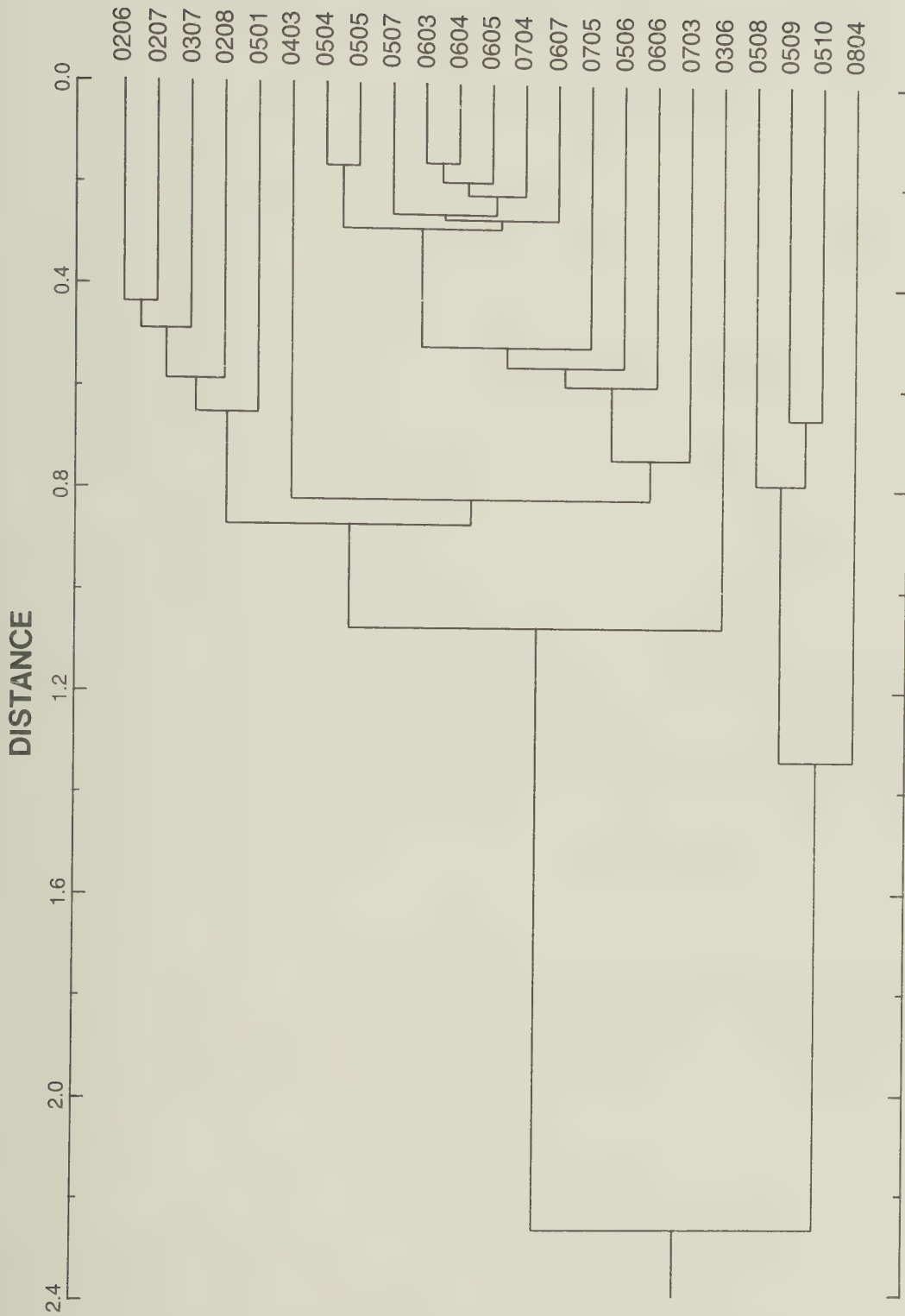


Fig. 9. Distance phenogram of 23 blocks for *Stenella attenuata* based on 36 characters and an unweighted pair group method using arithmetic averages (UPGMA). The cophenetic correlation is 0.97.

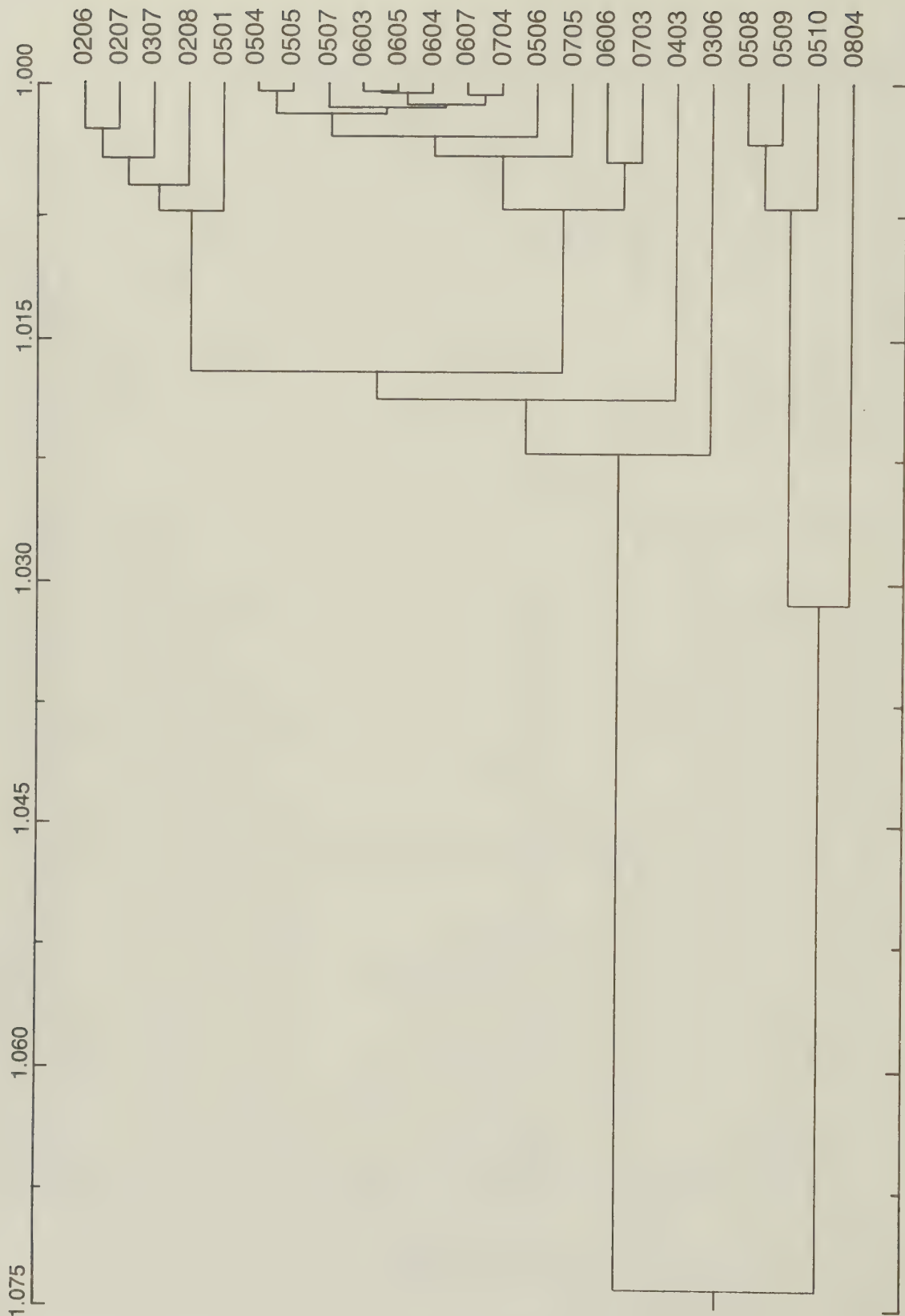


Fig. 10. Phenogram showing relationships among 23 blocks for Stenella attenuata based on 36 characters and use of adaptive hierarchical clustering scheme (AHCS).

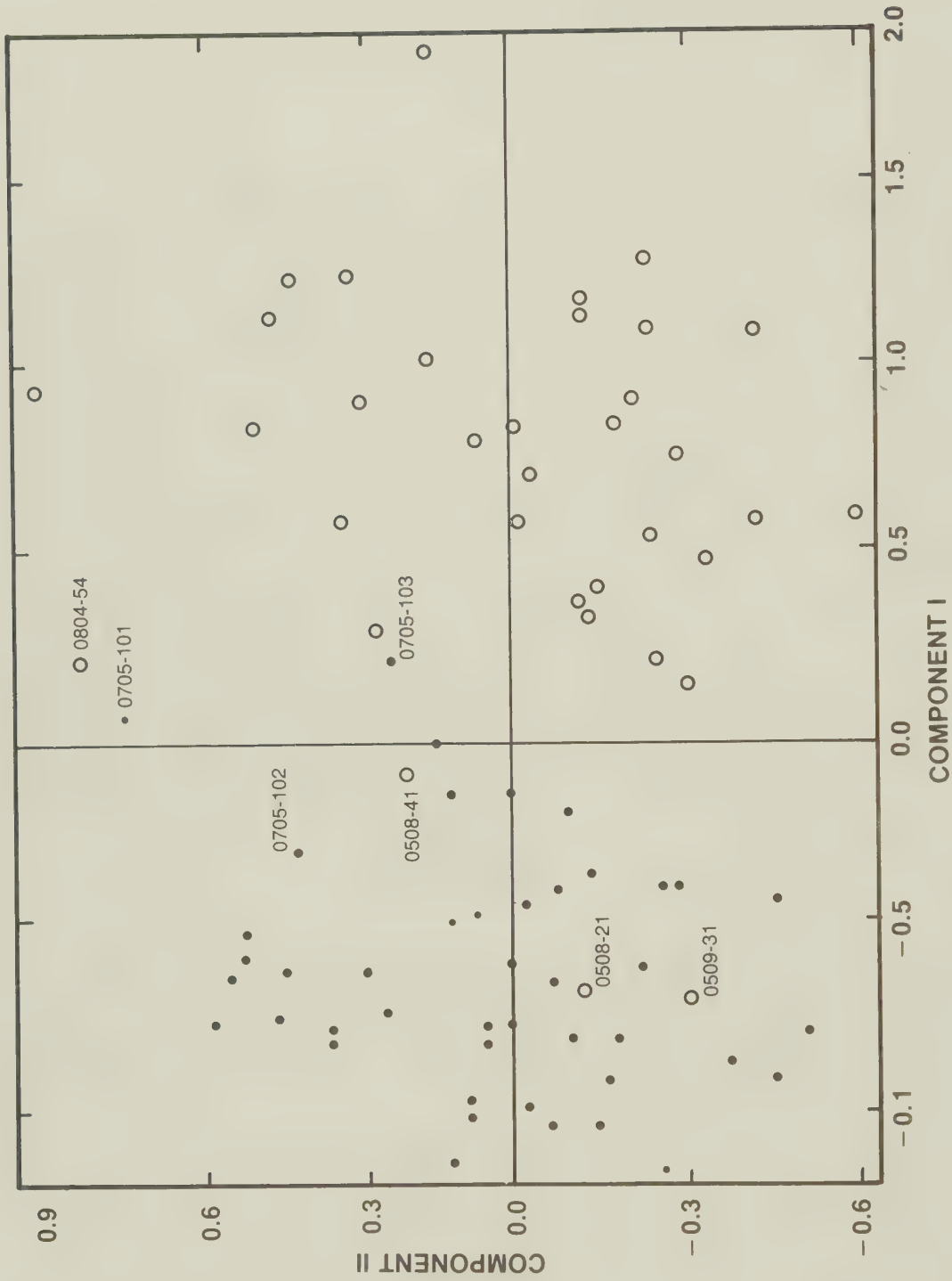


Fig. 12. Projections of individual specimens from the four onshore blocks (open circles) and blocks 0607 and 0705 (darkened circles) onto the first two principal components based on 36 characters for Stenella attenuata.

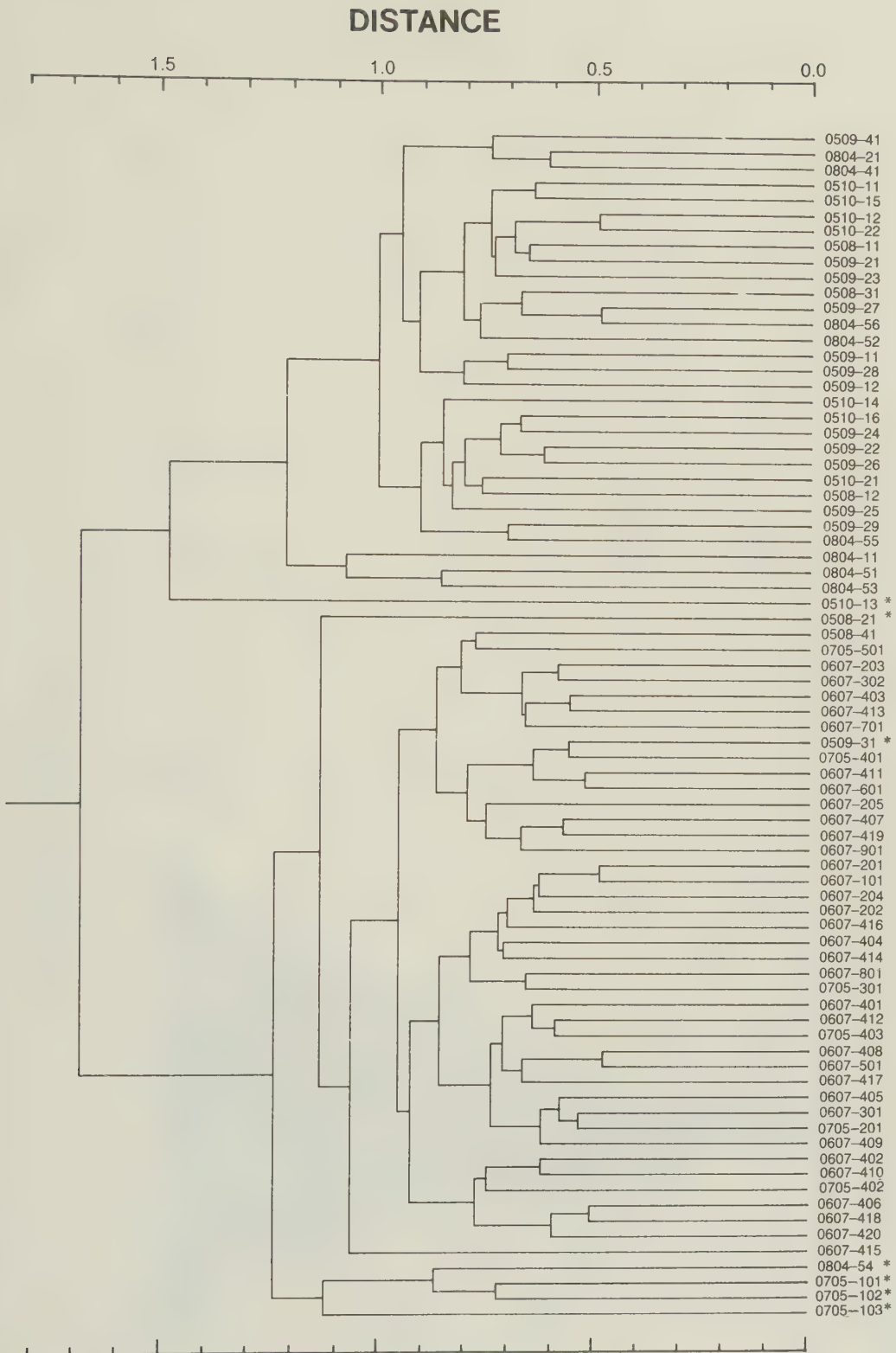


Fig. 13. Distance phenogram showing associations of specimens from onshore blocks with those from blocks 0607 and 0705. The animals marked with asterisks represent unknown specimens. Block and specimen numbers are identified on the right. The cophenetic correlation is 0.76.

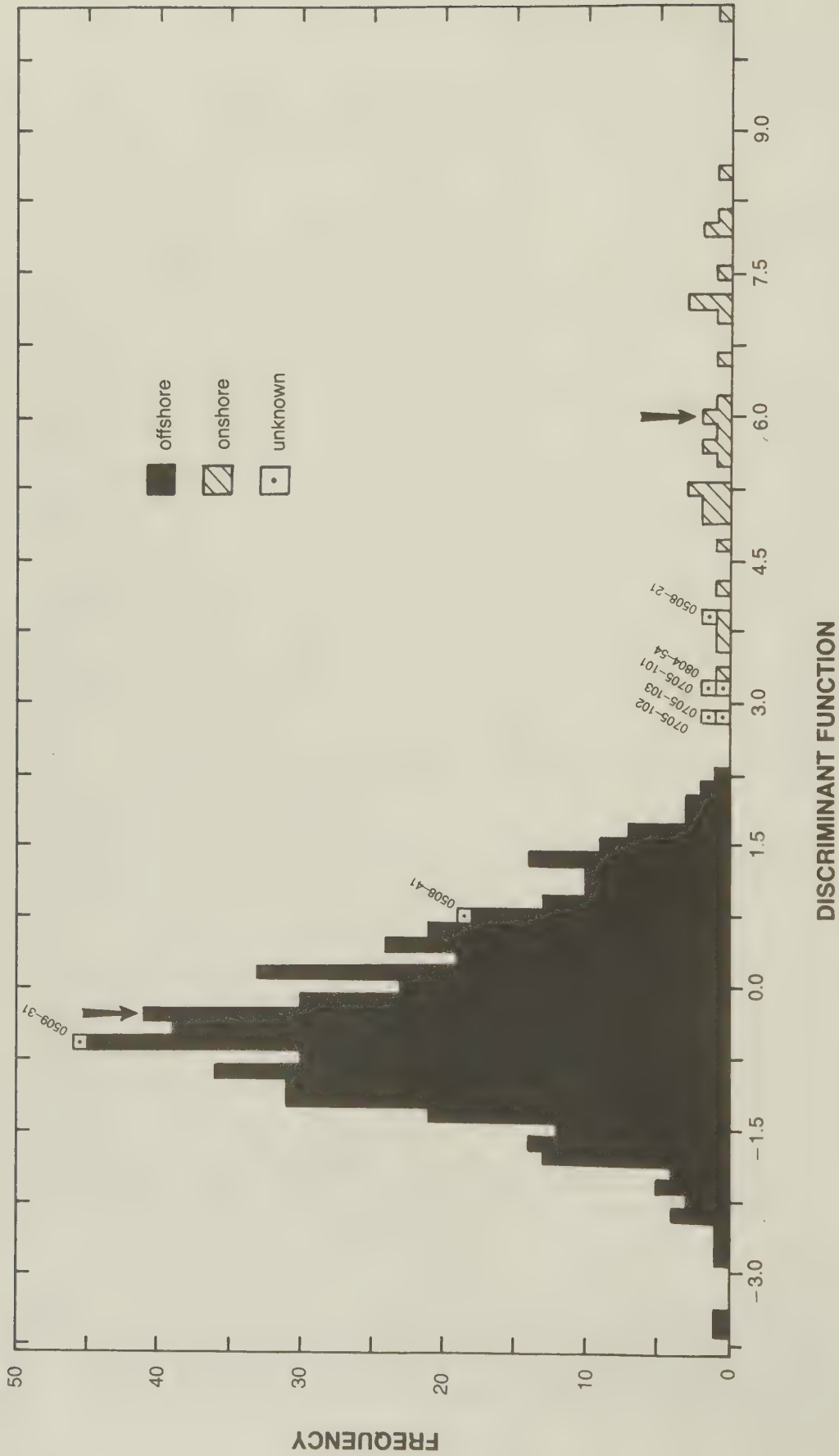


Fig. 14. Projections of *Stenella attenuata* specimens onto the discriminant function axis for offshore and onshore forms. Arrows indicate mean projection values for each form. Placements of unknown specimens are indicated.

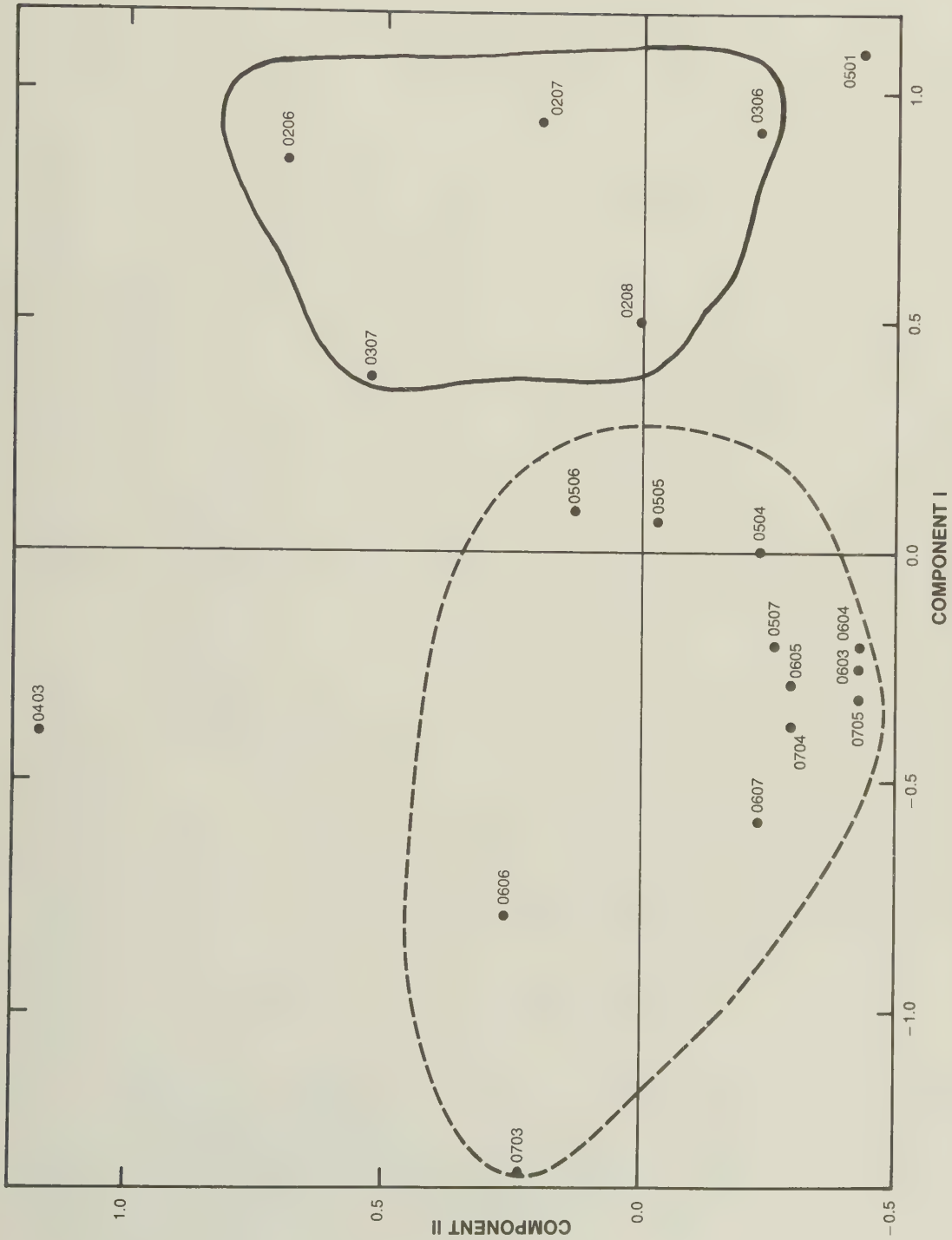


Fig. 15. Projections of 19 blocks of offshore Stenella attenuata onto the first two principal components based on 36 characters.



Fig. 18. Positions of 19 blocks of offshore *Stenella attenuata* on the first two canonical variables based on 36 characters.

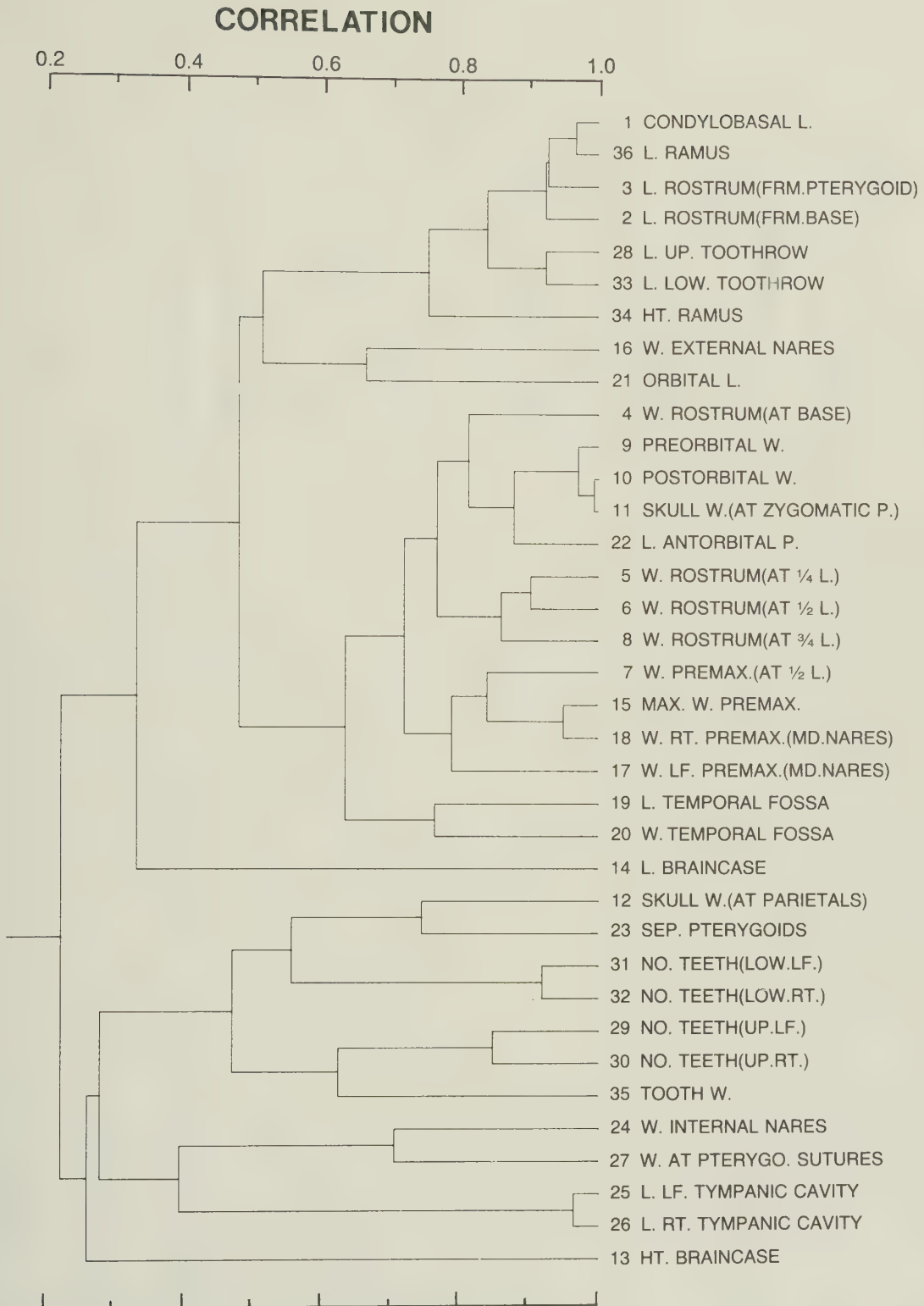


Fig. 19. Dendrogram showing correlations among characters based on block means for the 19 blocks of offshore *Stenella attenuata*. Clustering was accomplished using UPGMA on the absolute correlation values among characters (i.e., negative signs were removed). The cophenetic correlation is 0.80.

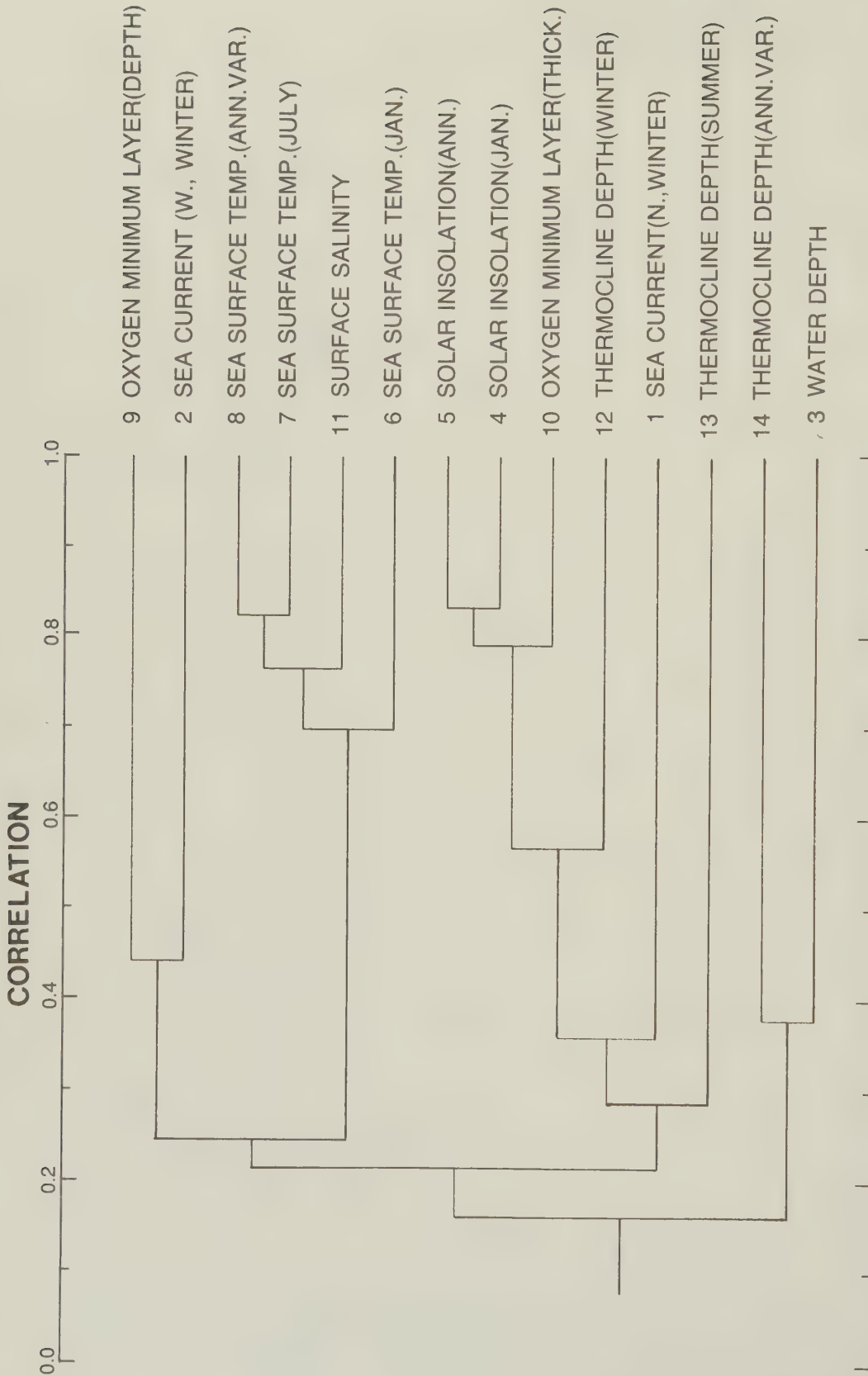


Fig. 20. Dendrogram summarizing associations among environmental variables. Clustering by UPGMA on the absolute correlation values among variables (i.e., negative signs removed). The cophenetic correlation is 0.83.

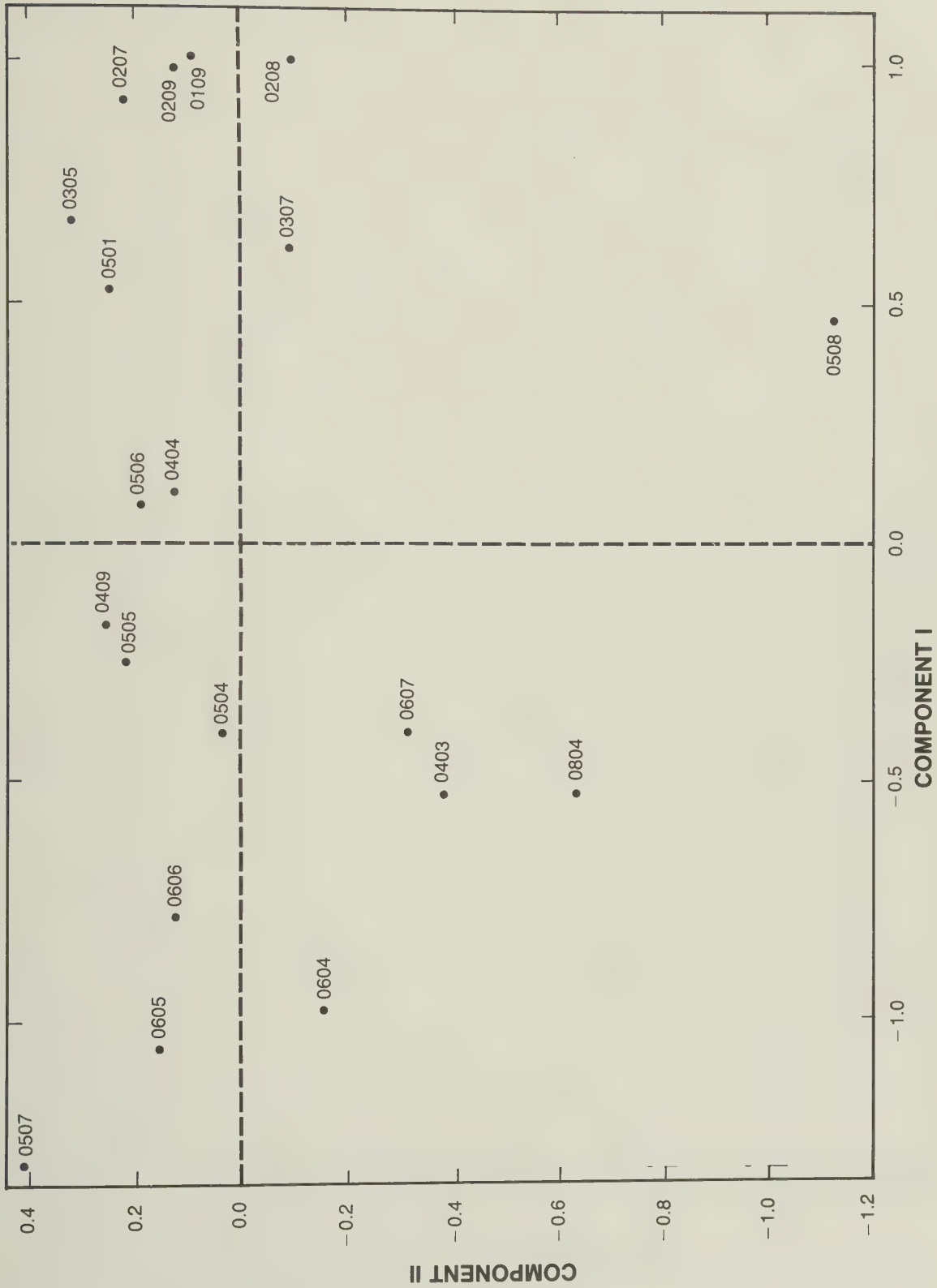


Fig. 21. Projections of 20 blocks of *Stenella longirostris* onto the first two principal components based on 36 characters.

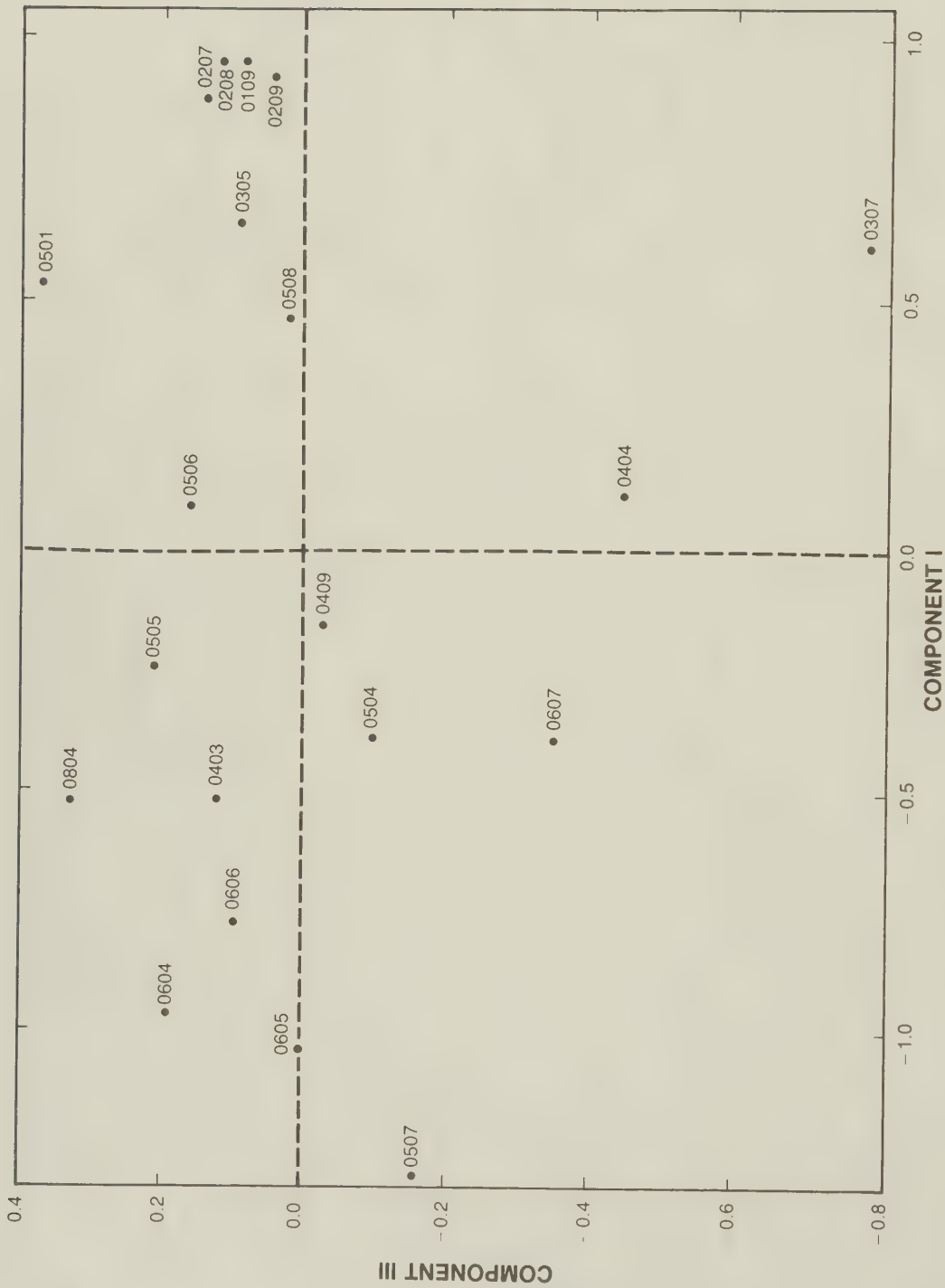


Fig. 22. Projections of 20 blocks of *Stenella longirostris* onto principal components I and III based on 36 characters.

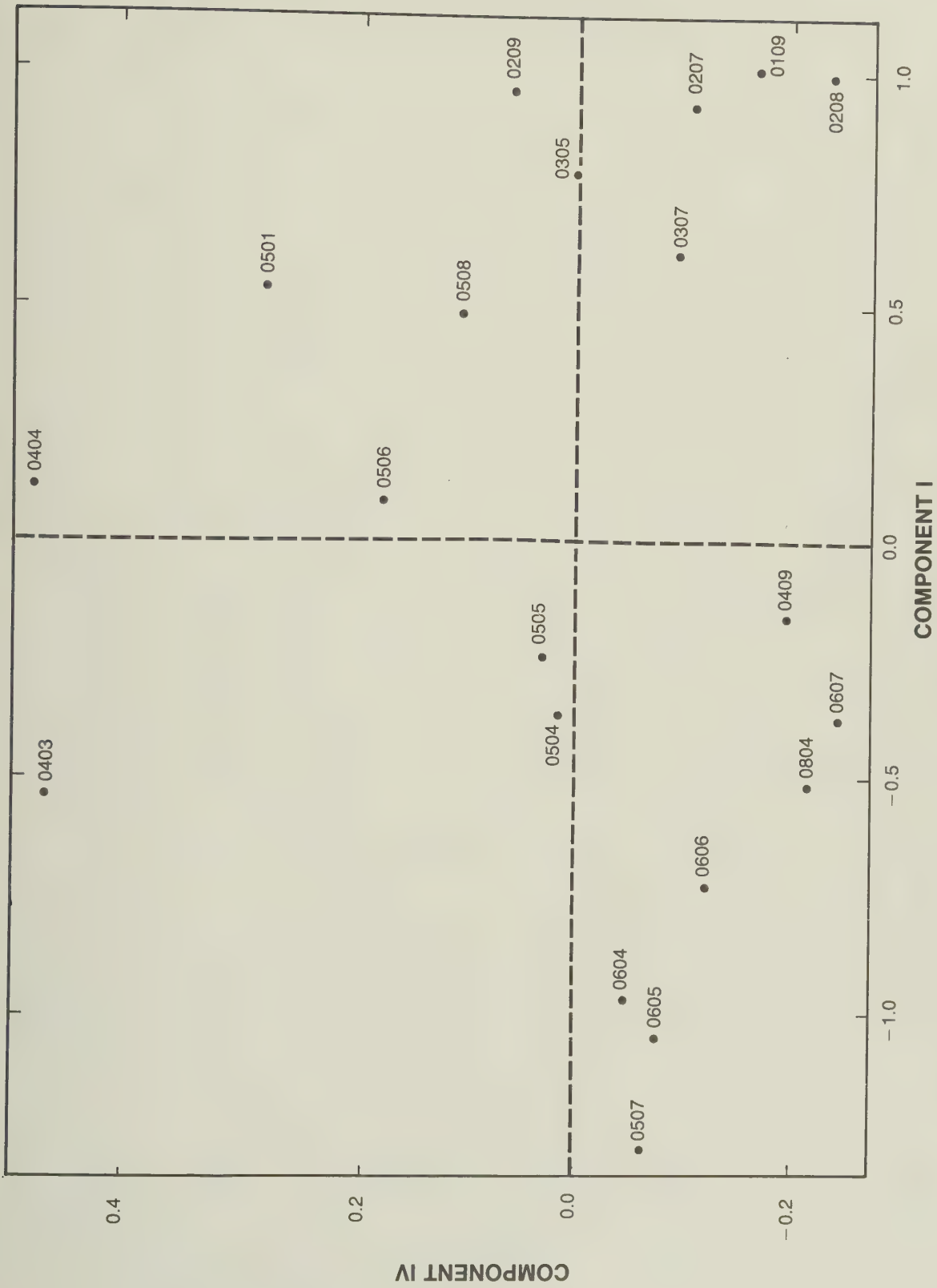


Fig. 23. Projections of 20 blocks of *Stenella longirostris* onto principal components I and IV based on 36 characters.

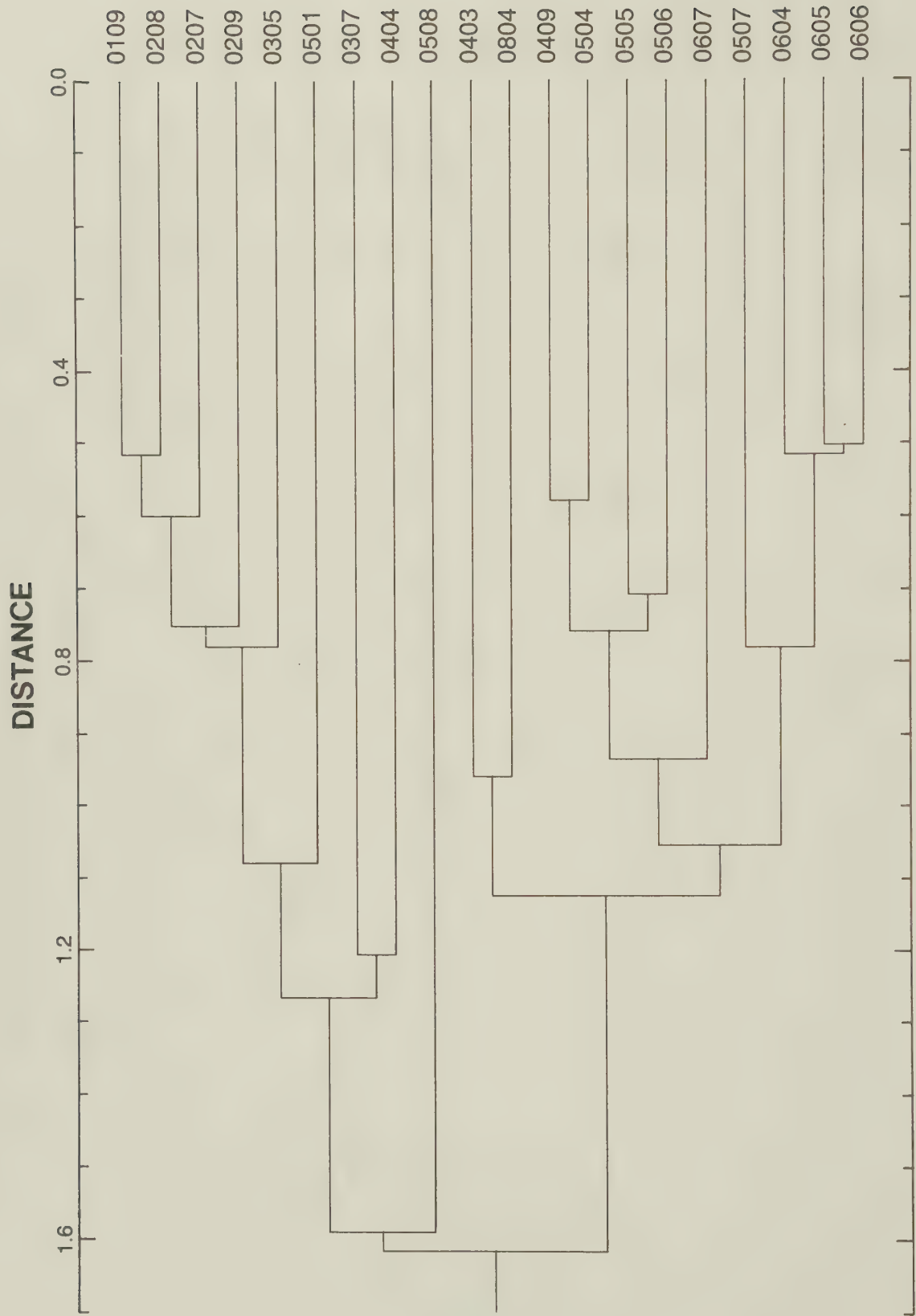


Fig. 24. Distance phenogram of 20 blocks for *Stenella longirostris* based on 36 characters with UPGMA clustering. The cophenetic correlation is 0.77.

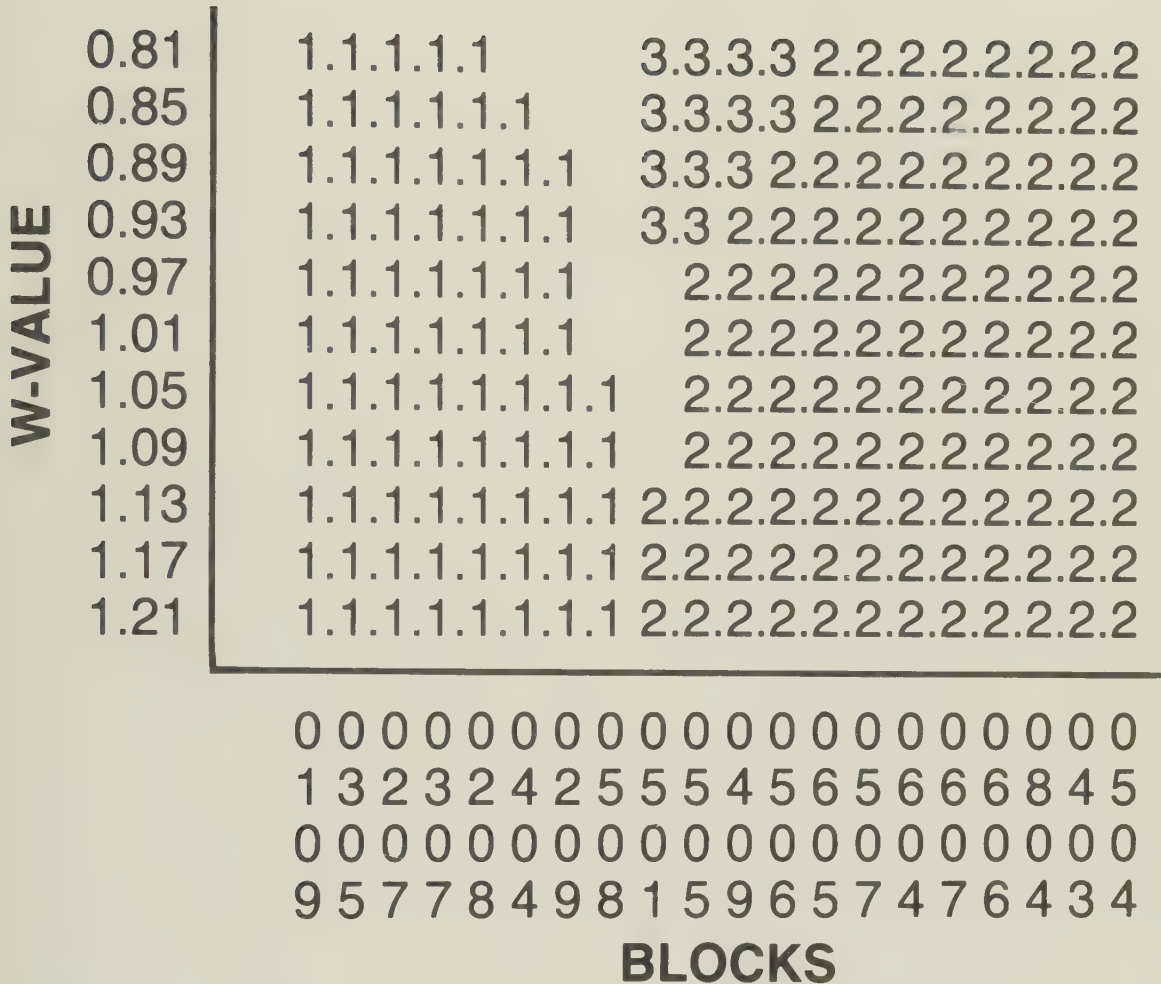


Fig. 27. Generalized skyline diagram for 20 blocks of Stenella longirostris indicating groups formed using function-point clustering procedures for five selected characters. Blocks with the same number for a particular w value are in the same cluster; those represented by a blank are in a group by themselves.

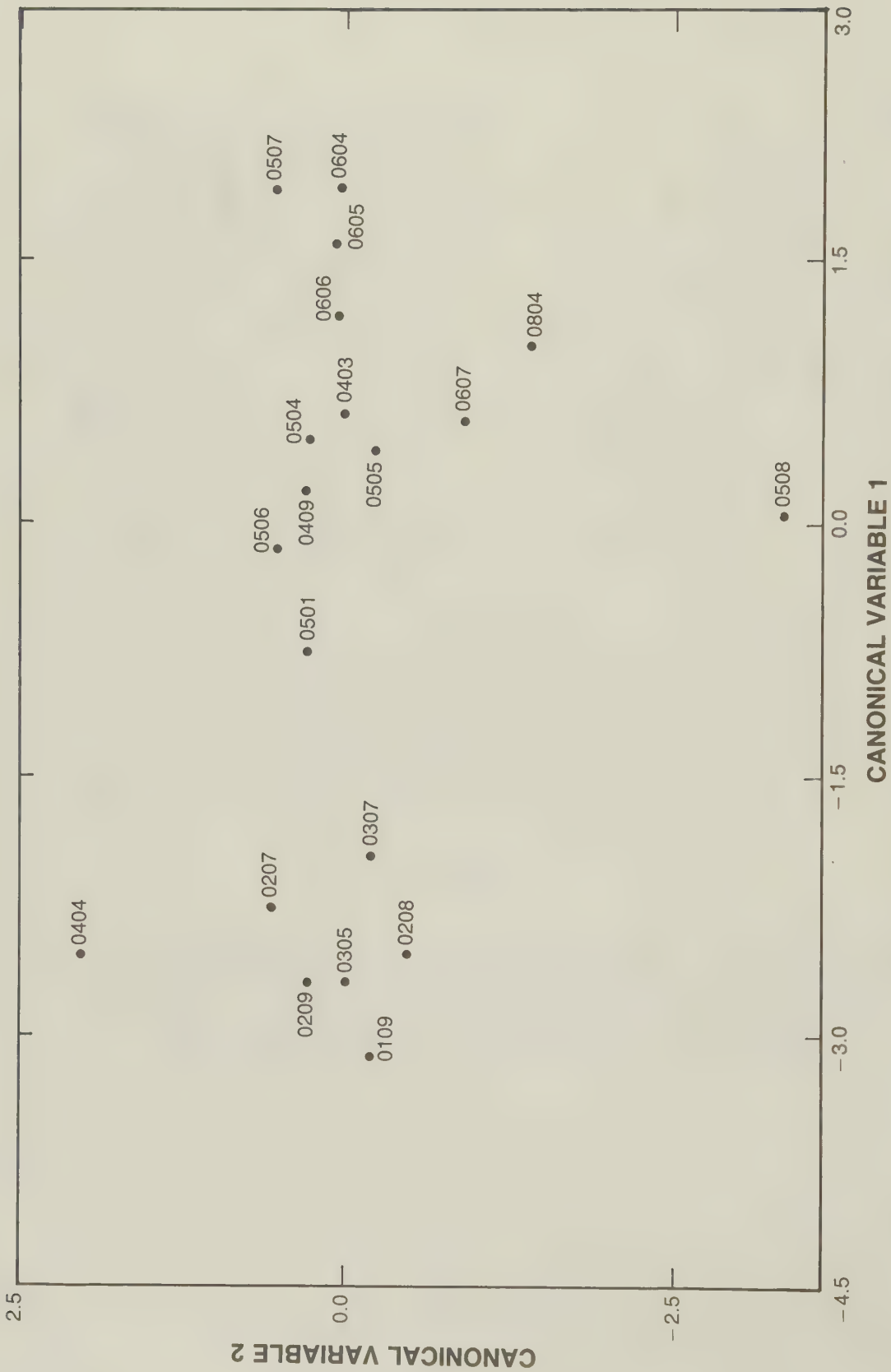


Fig. 28. Positions of 20 blocks of *Stenella longirostris* on first two canonical variables based on 36 characters.

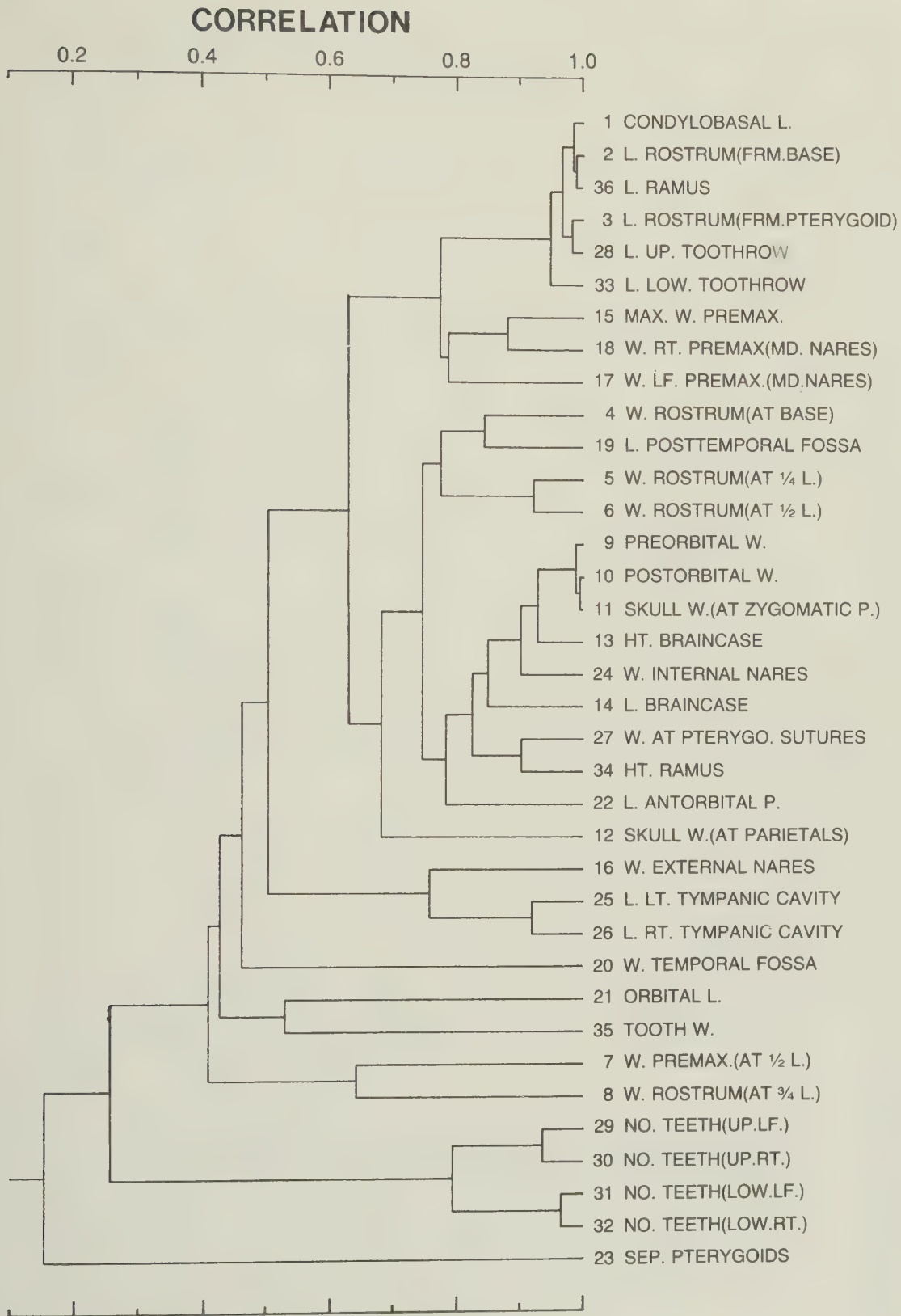
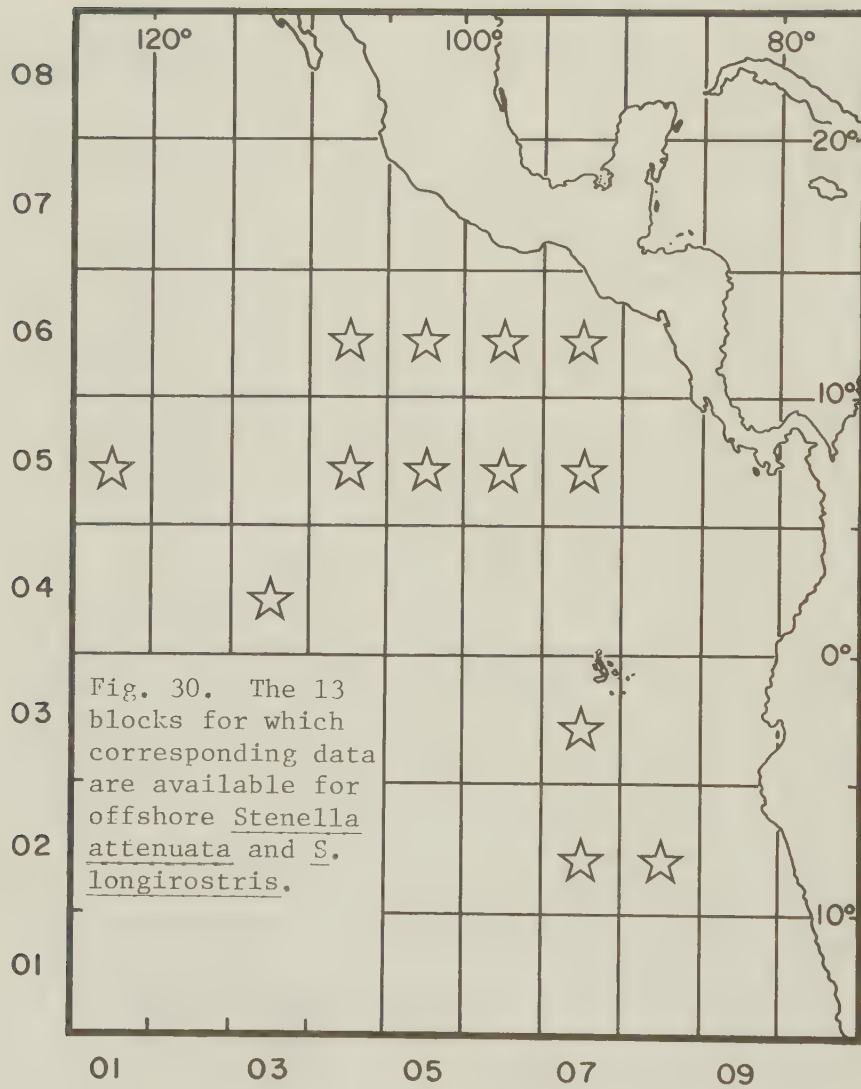
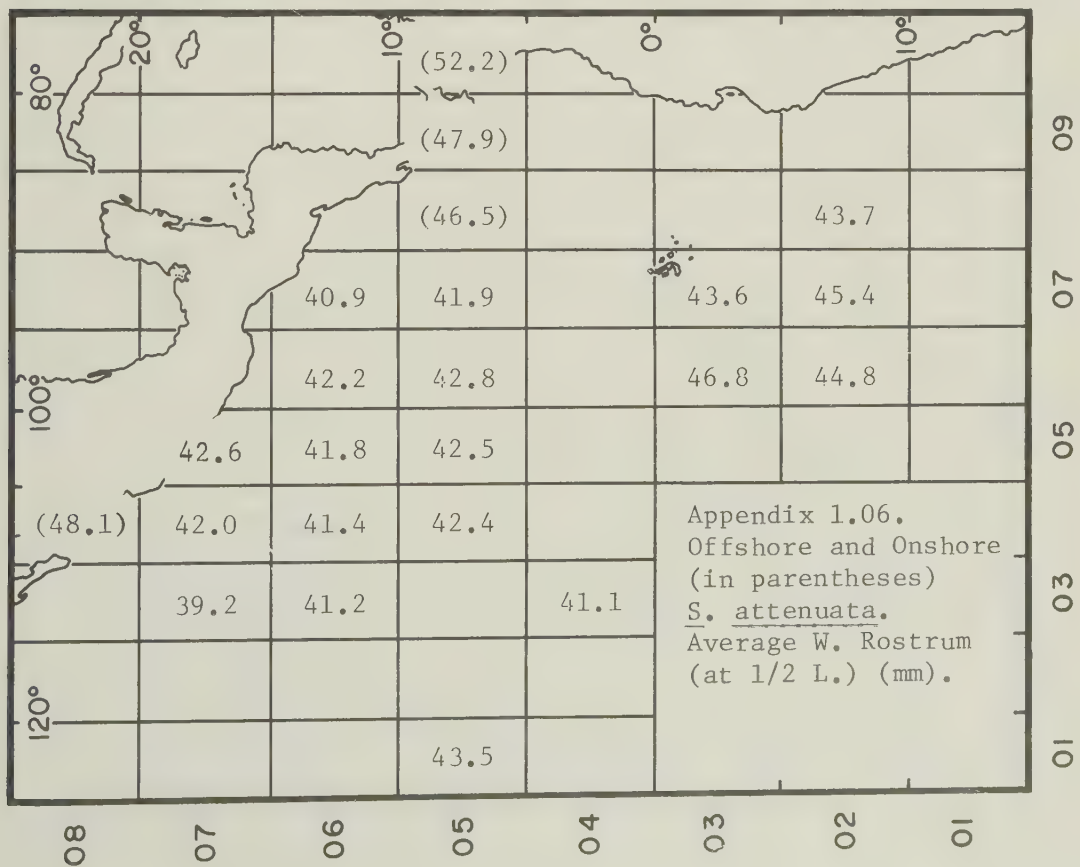
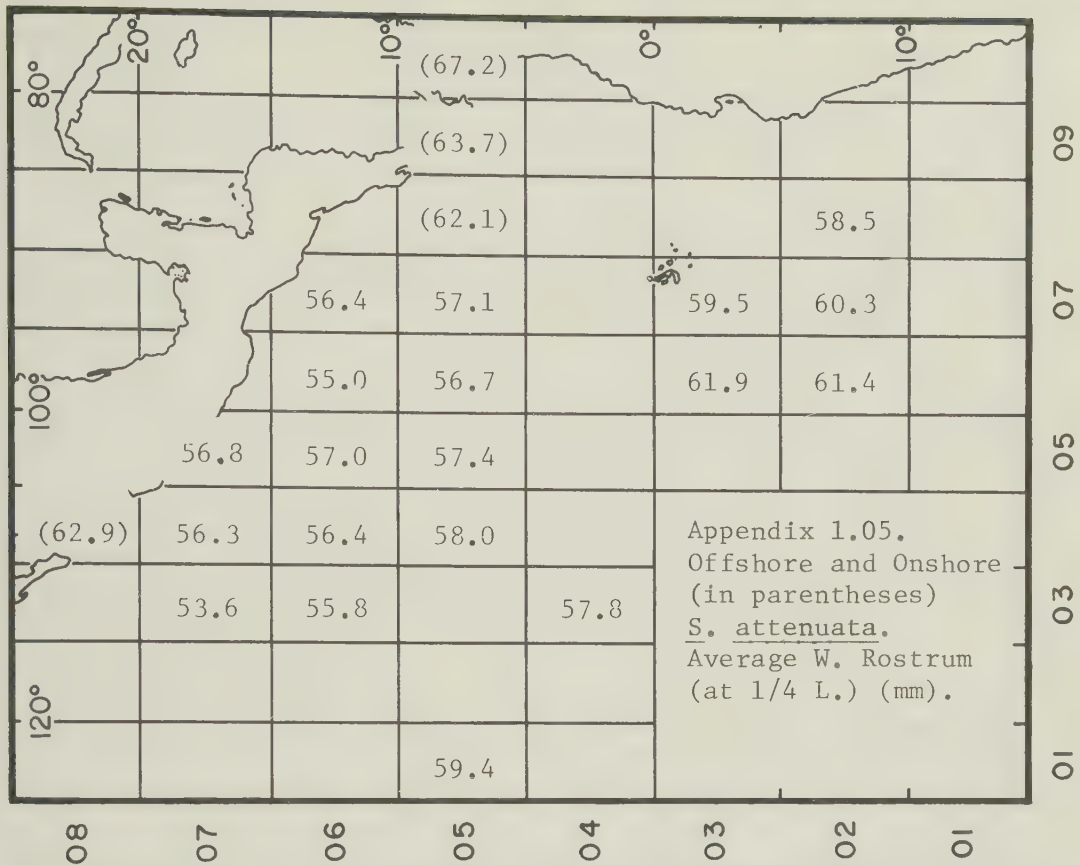
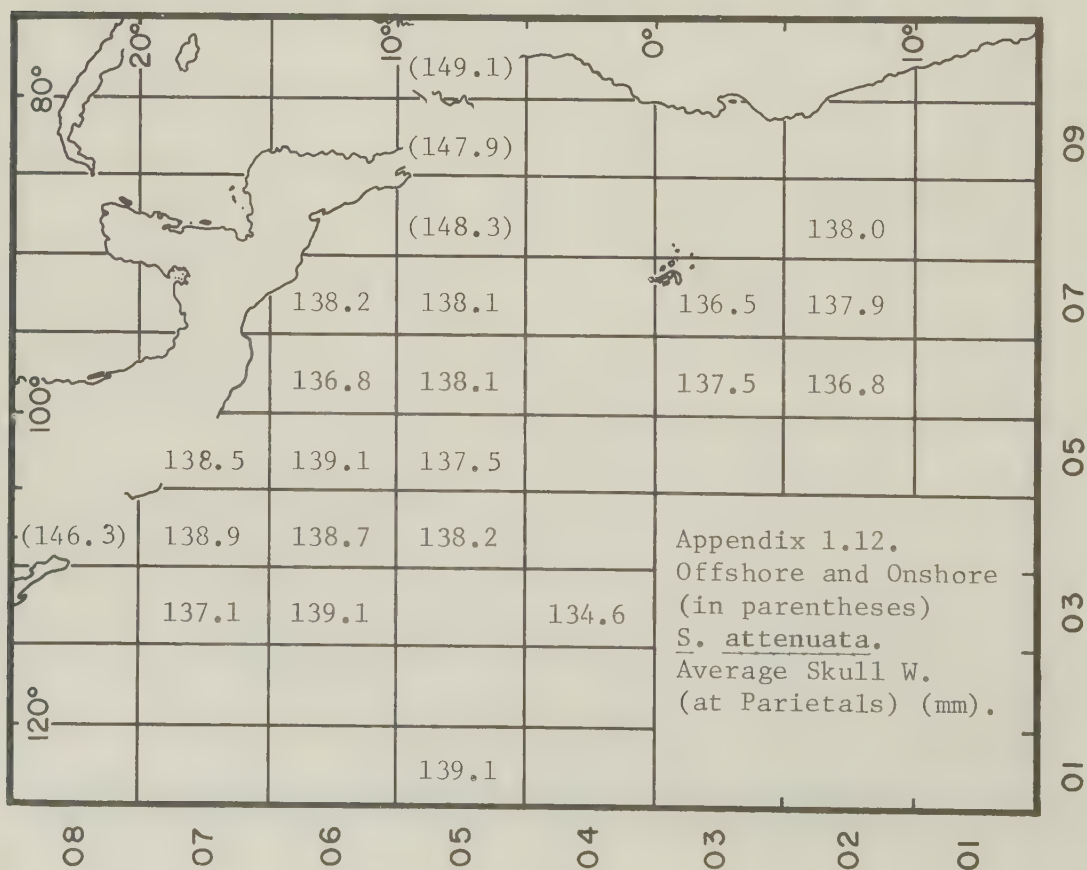
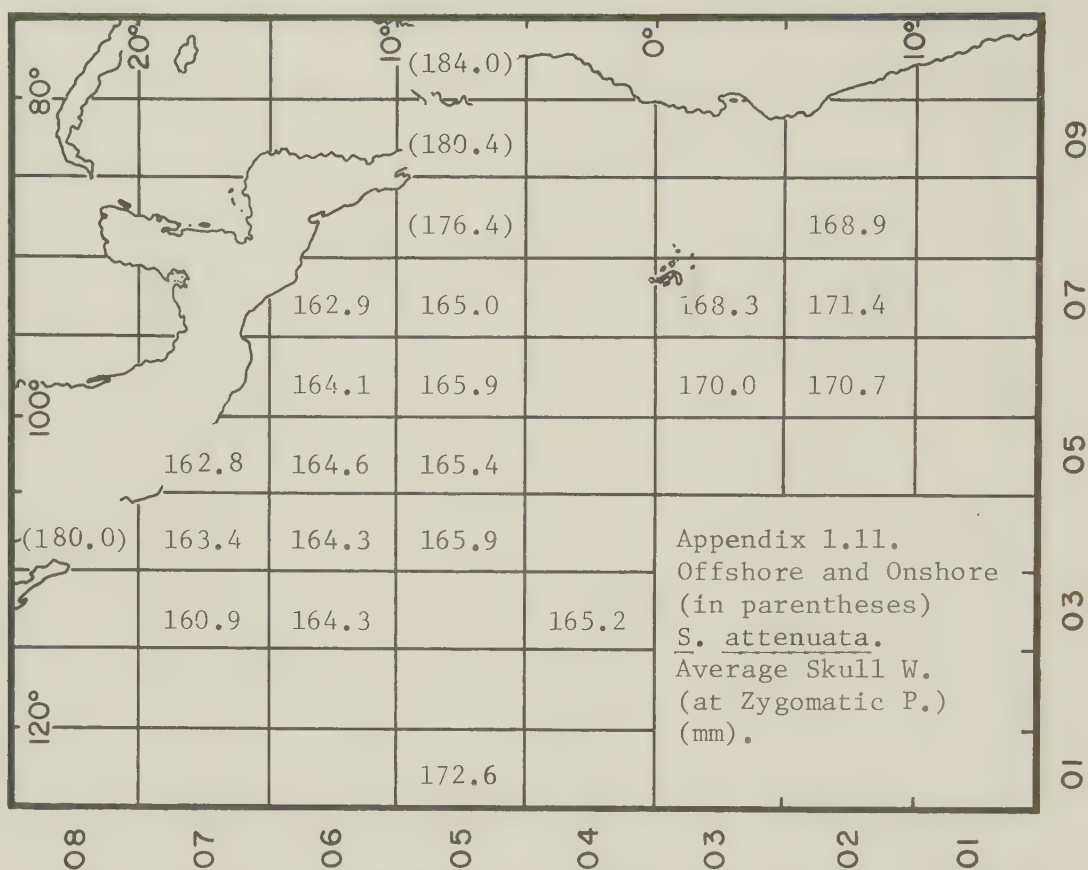
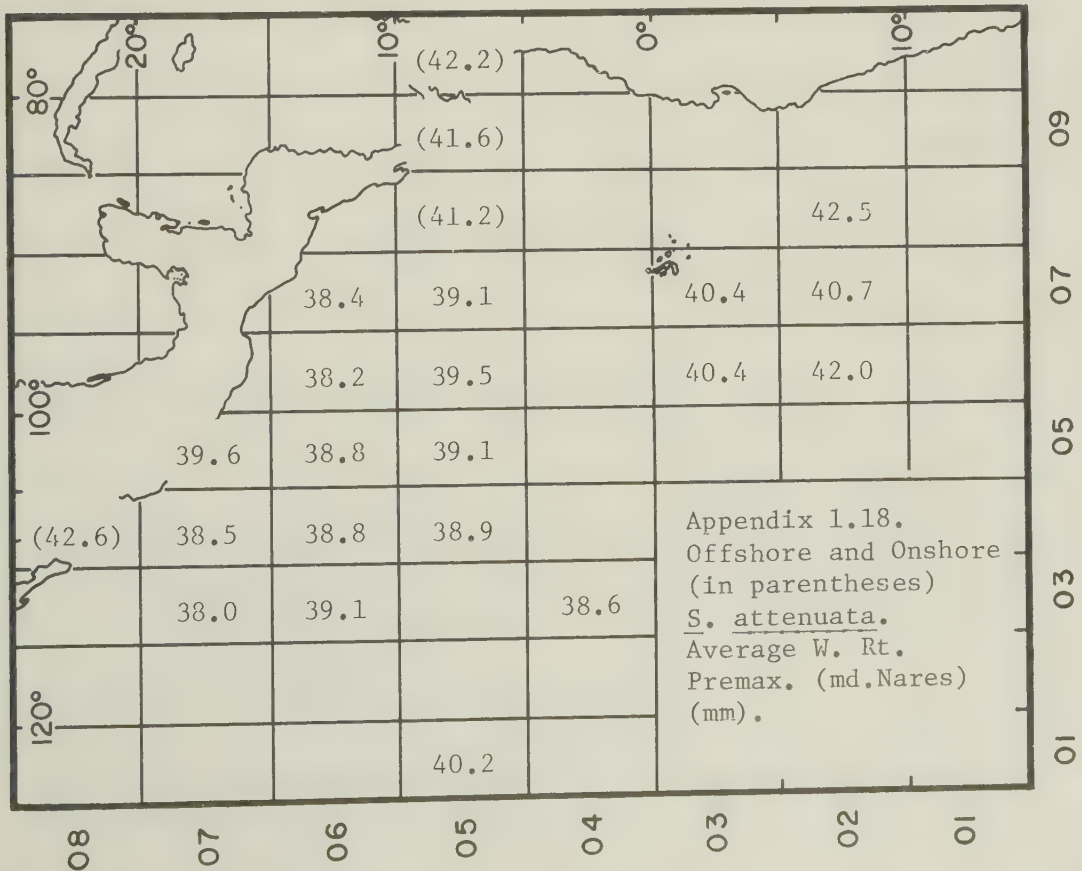
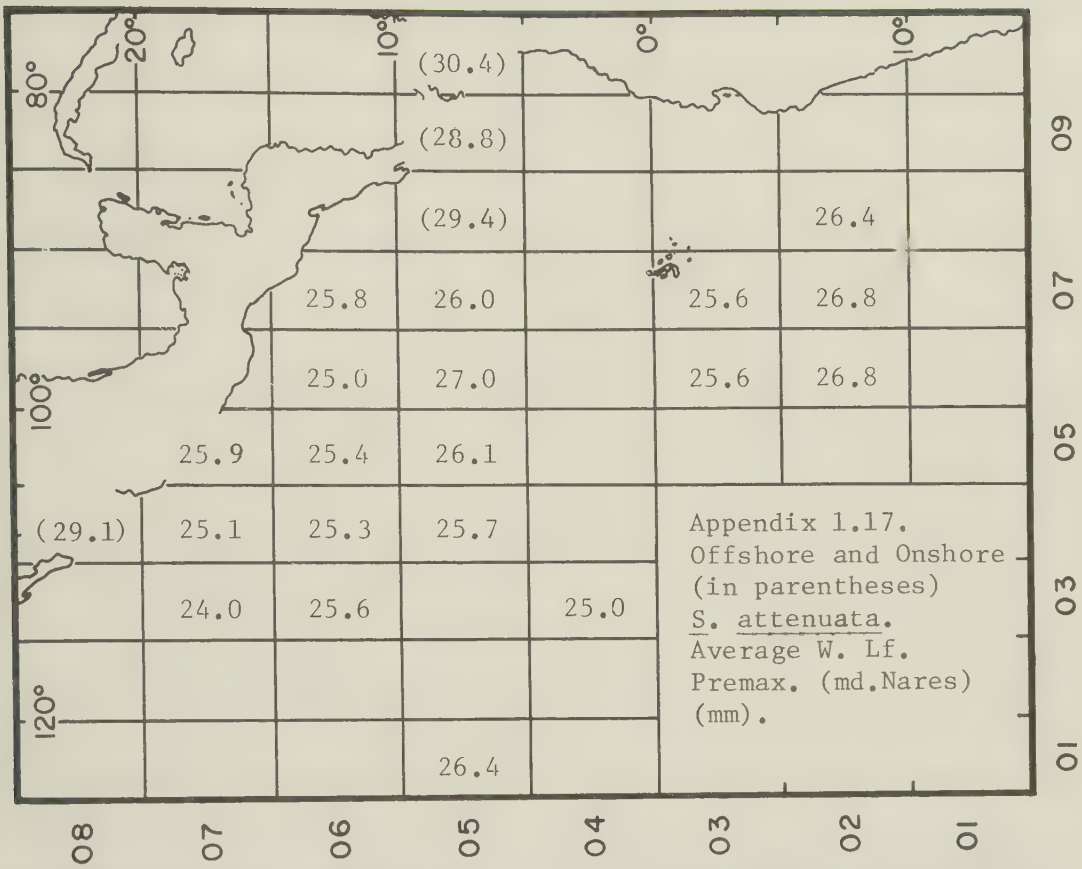


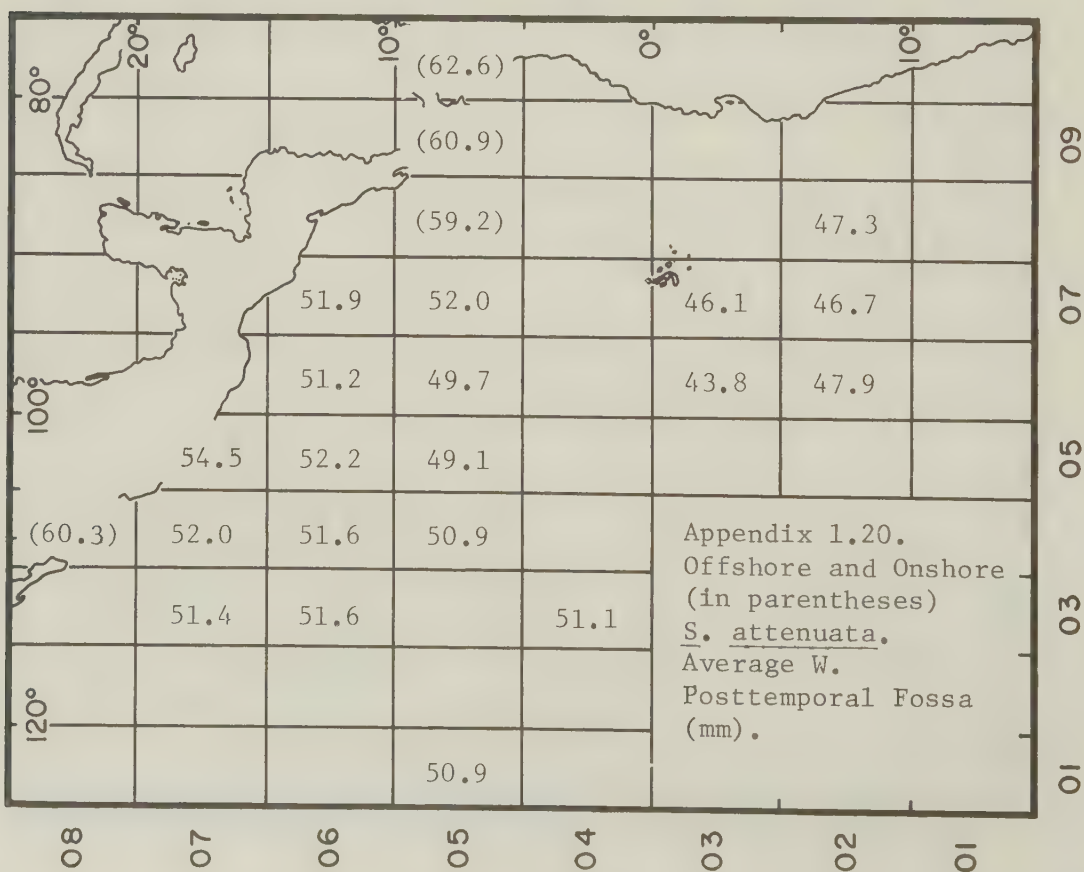
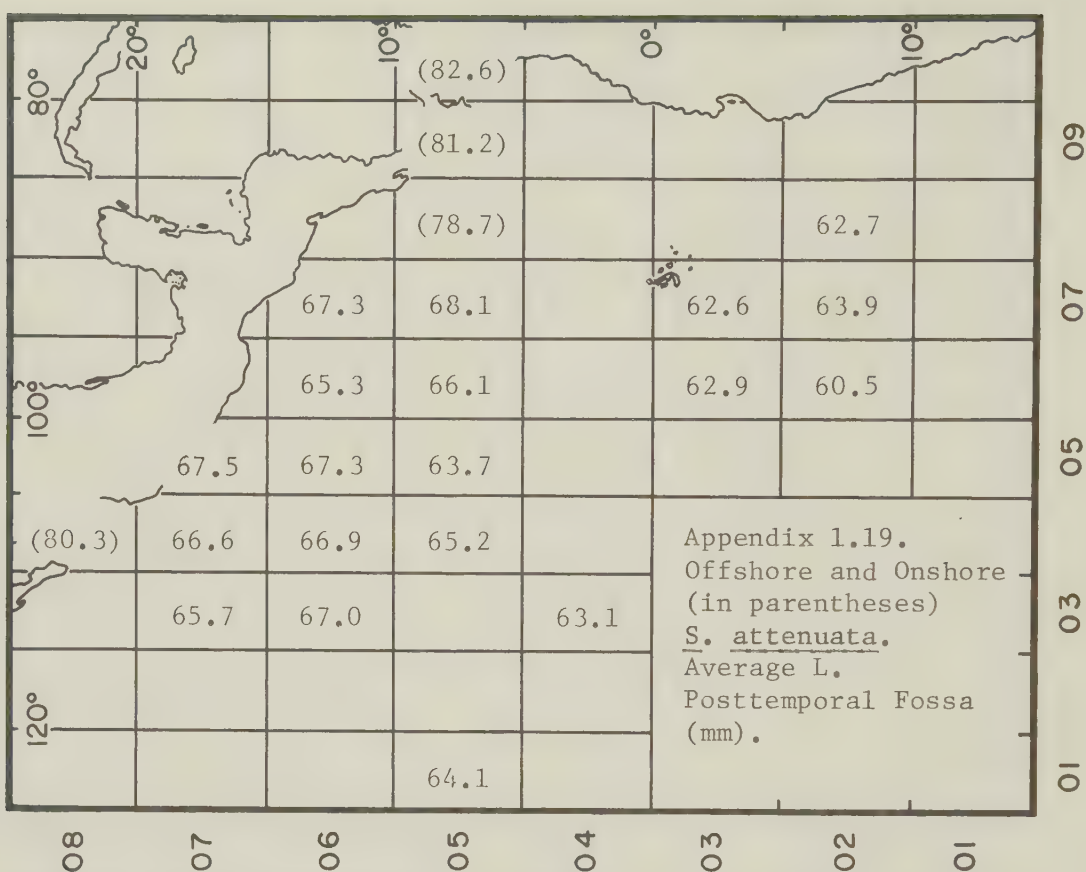
Fig. 29. Dendrogram showing correlations among characters based on block means for the 20 blocks of *Stenella longirostris*. Clustering was accomplished using UPGMA on the absolute correlation values among characters (i.e., negative signs removed). The cophenetic correlation is 0.85.

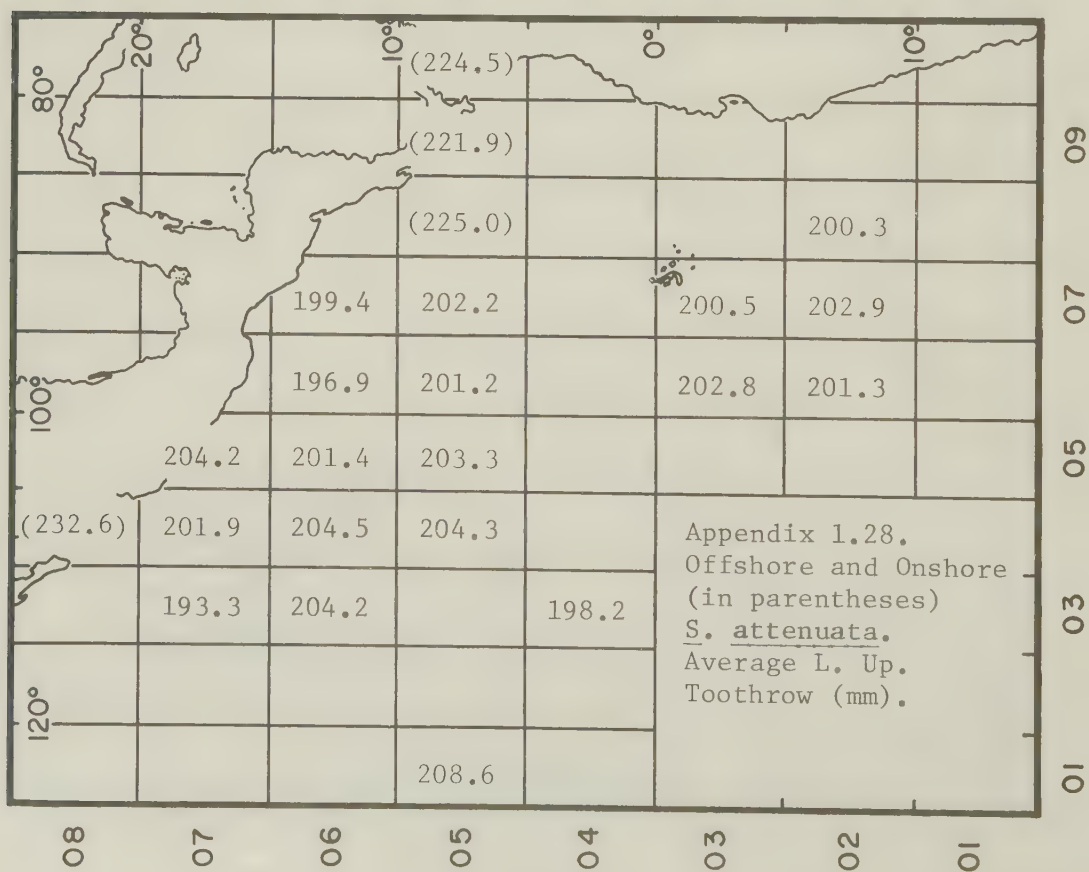
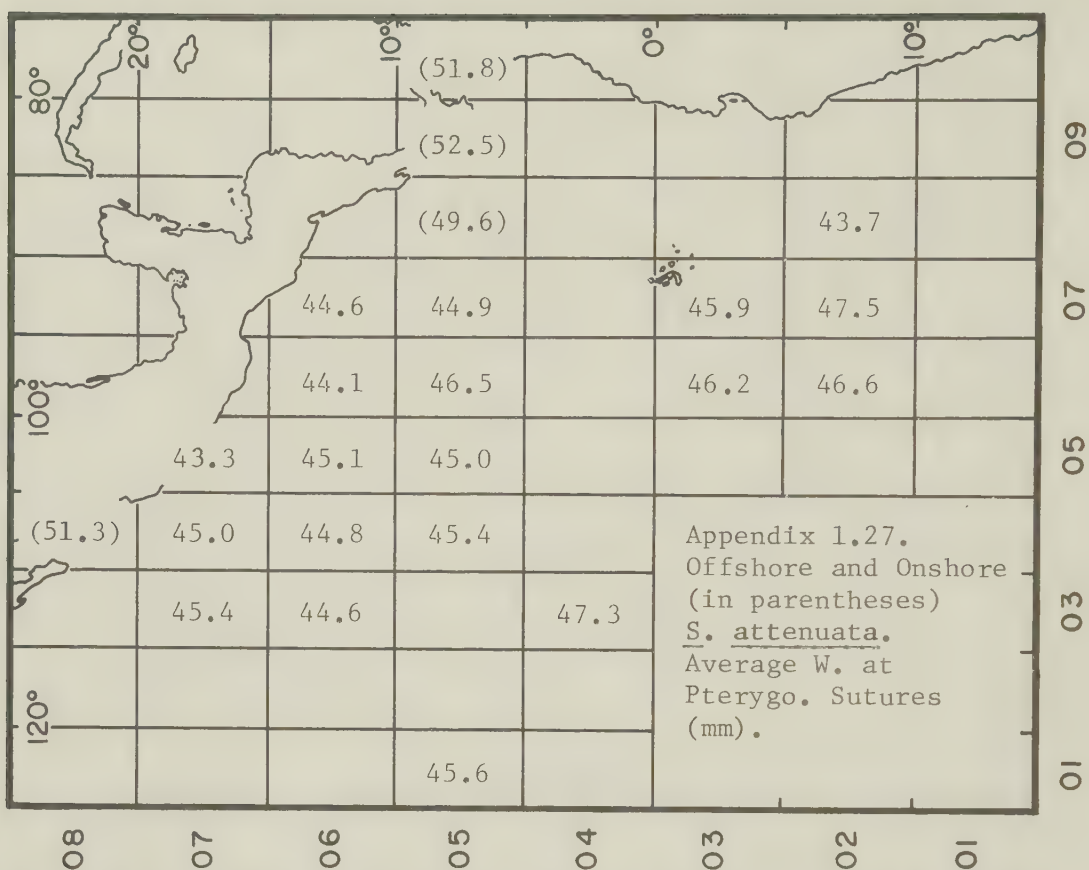


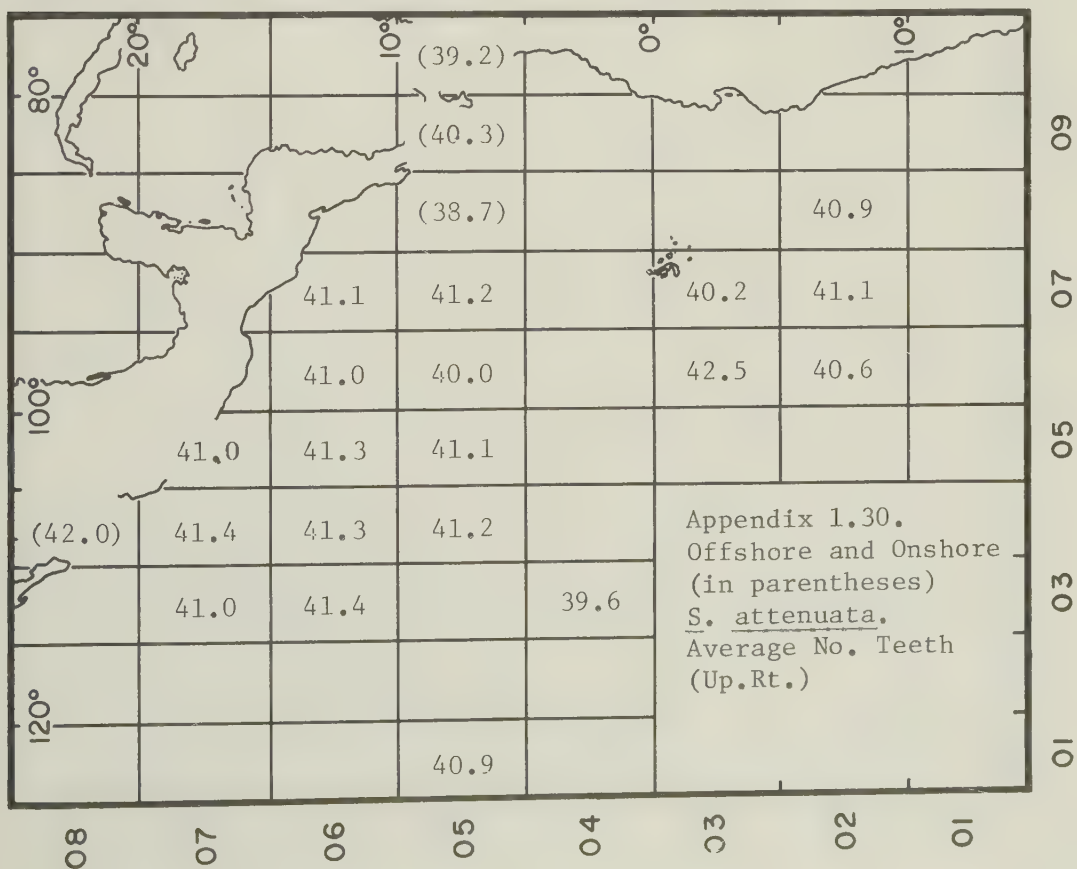
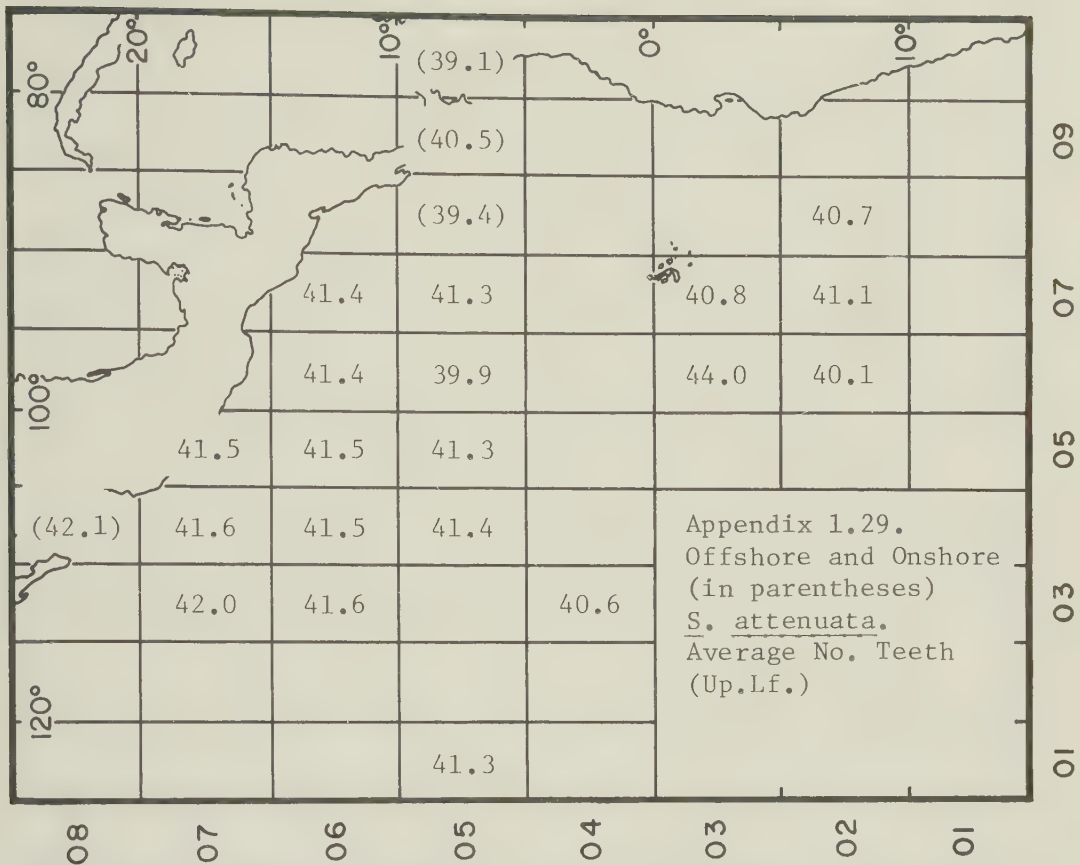


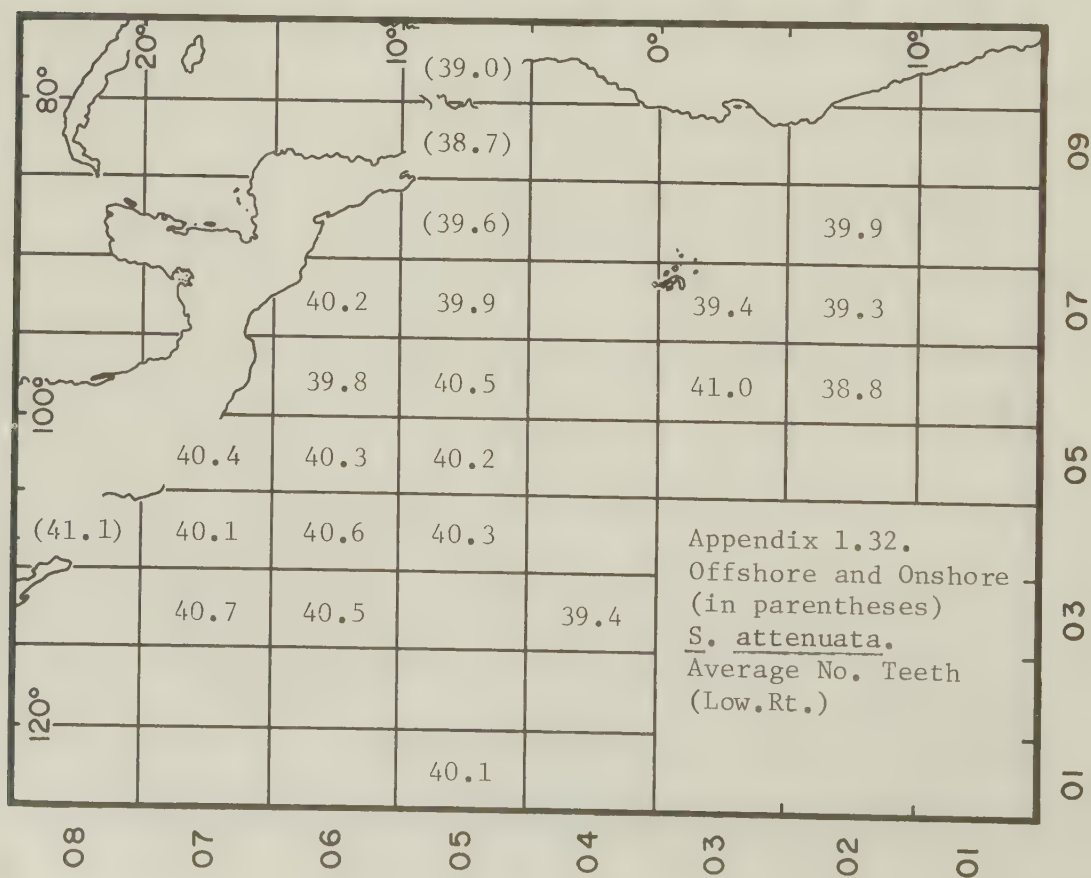


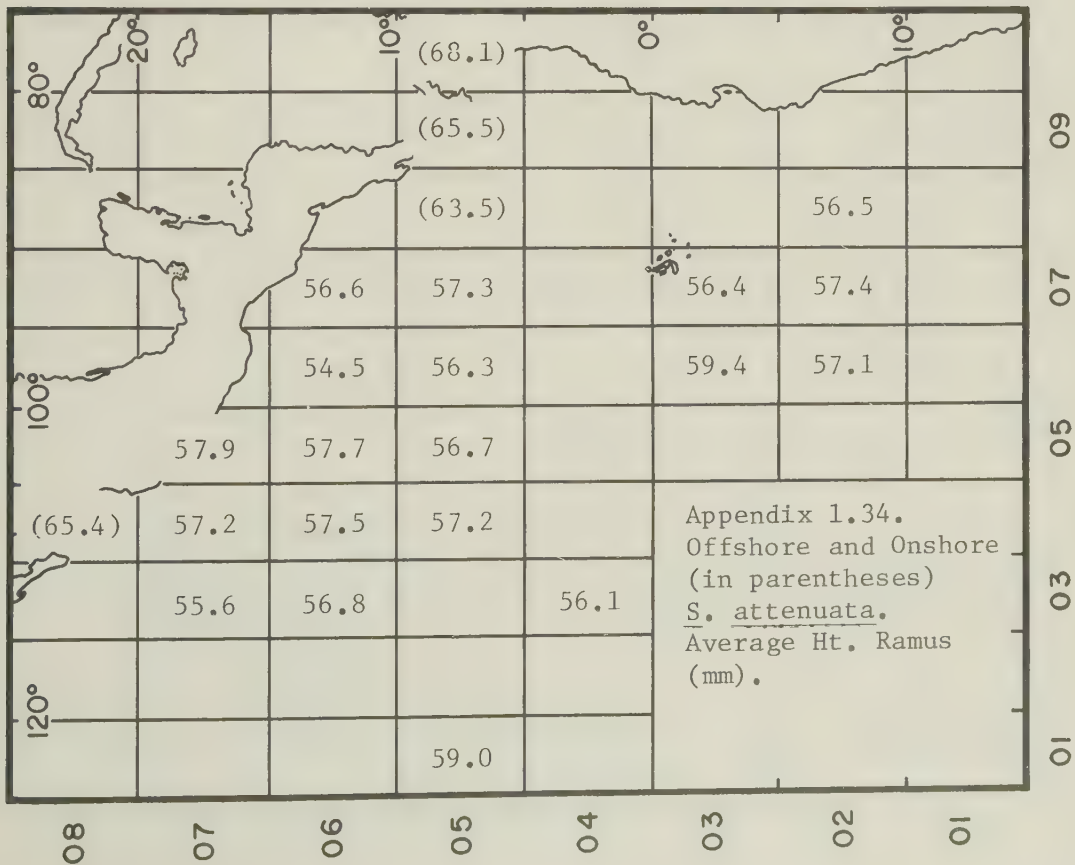
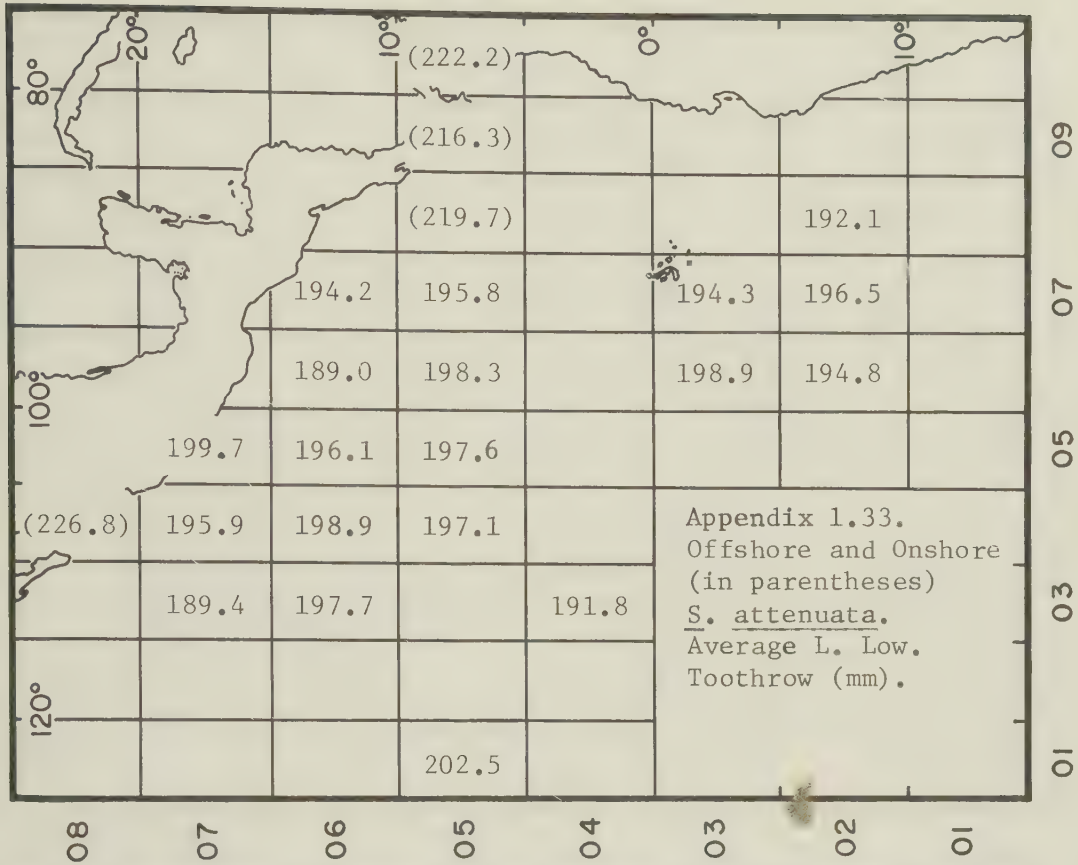


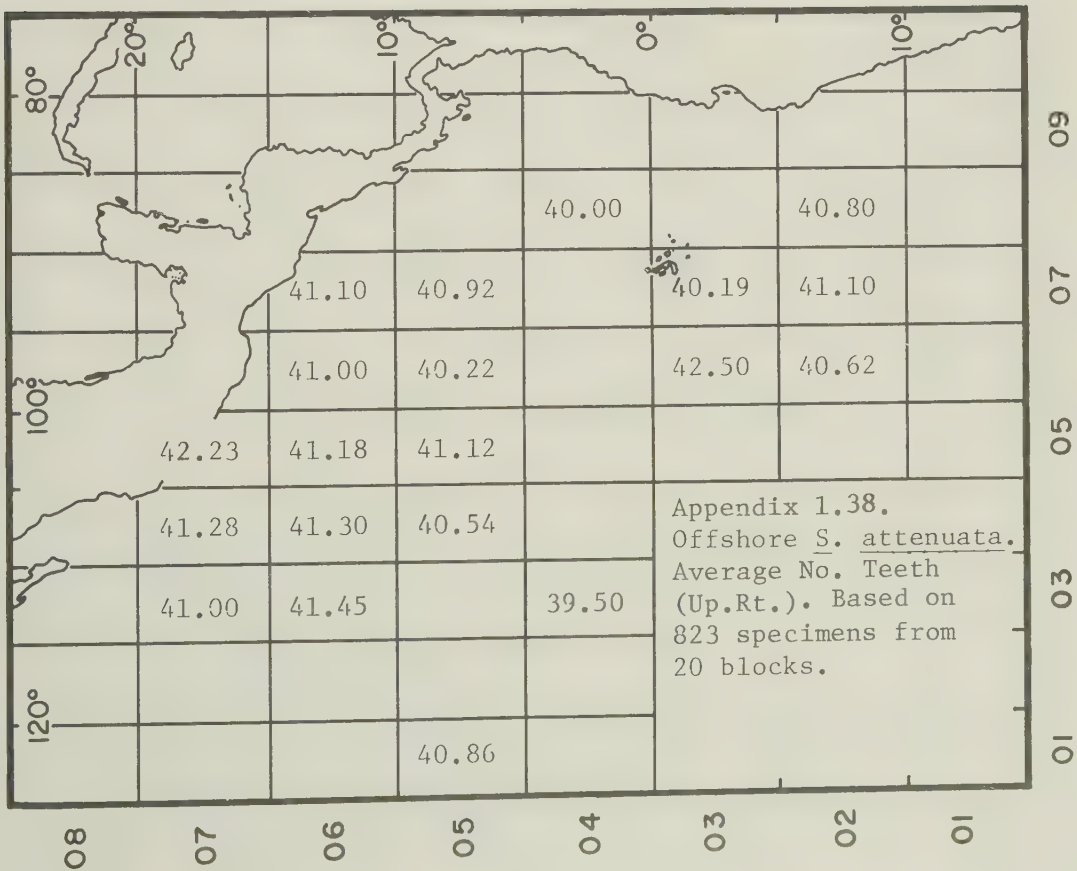
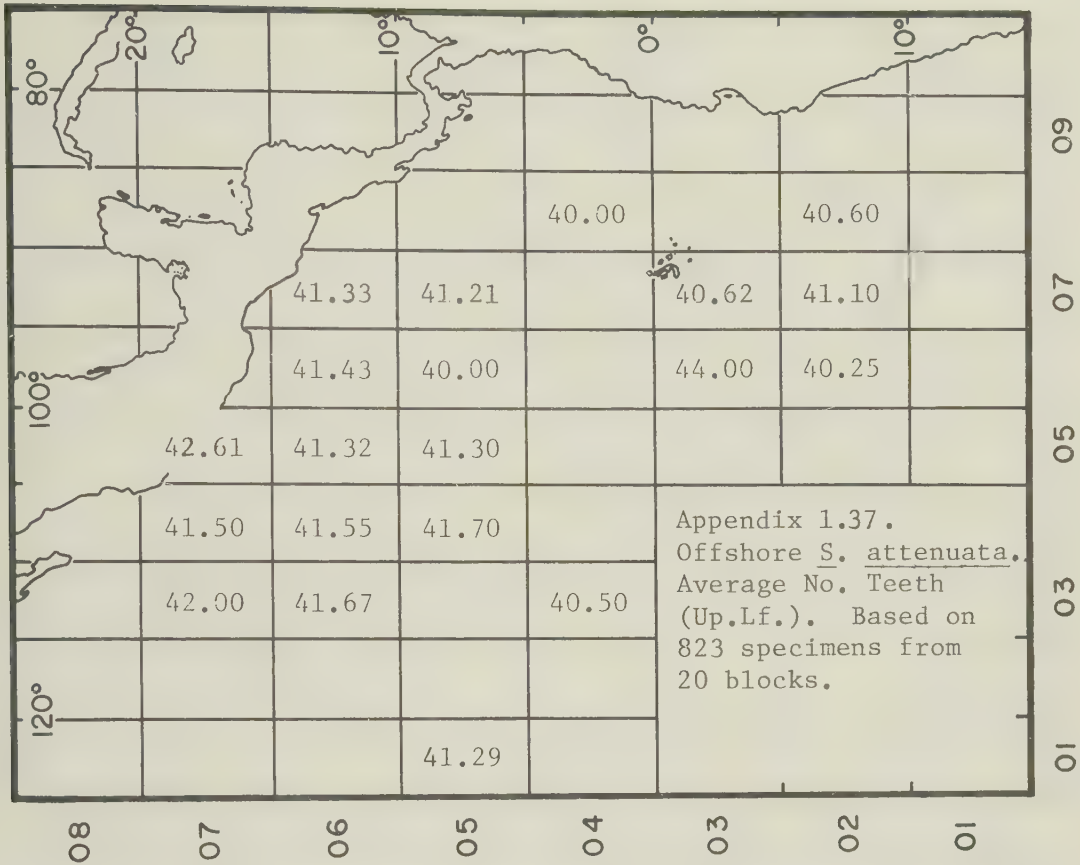


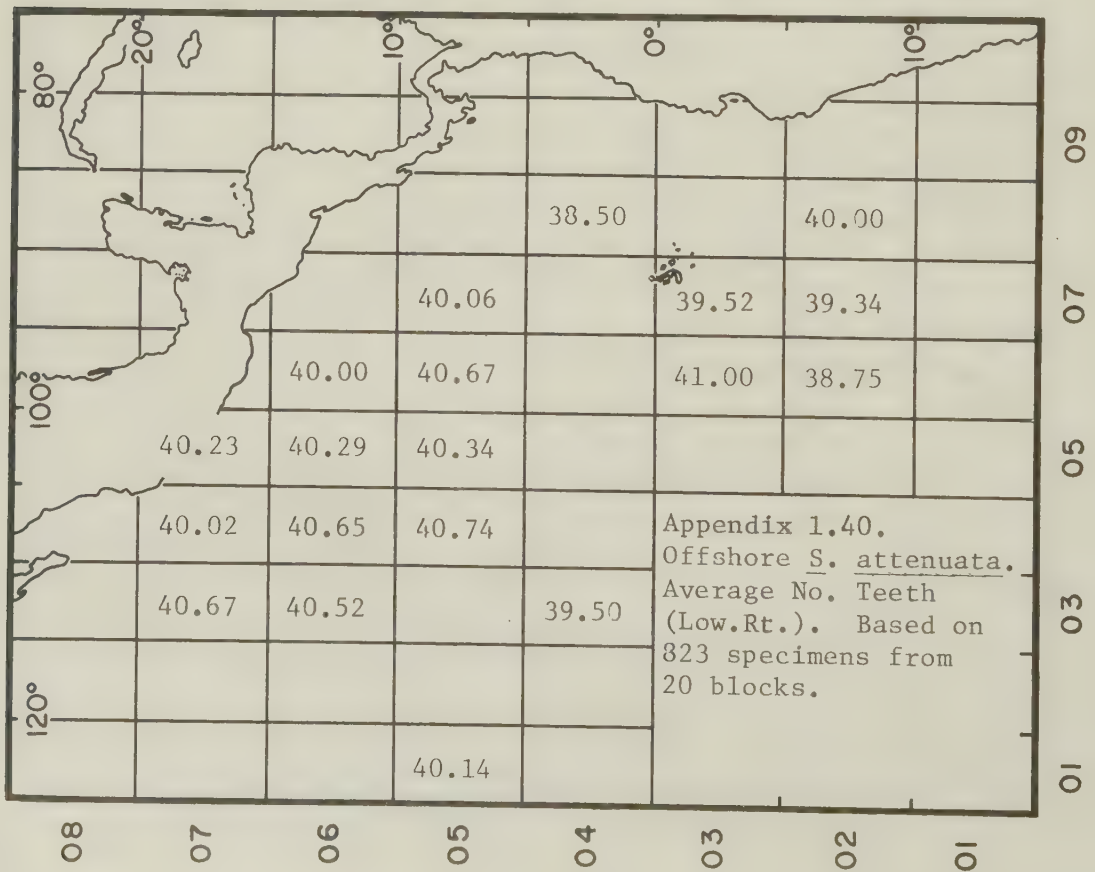
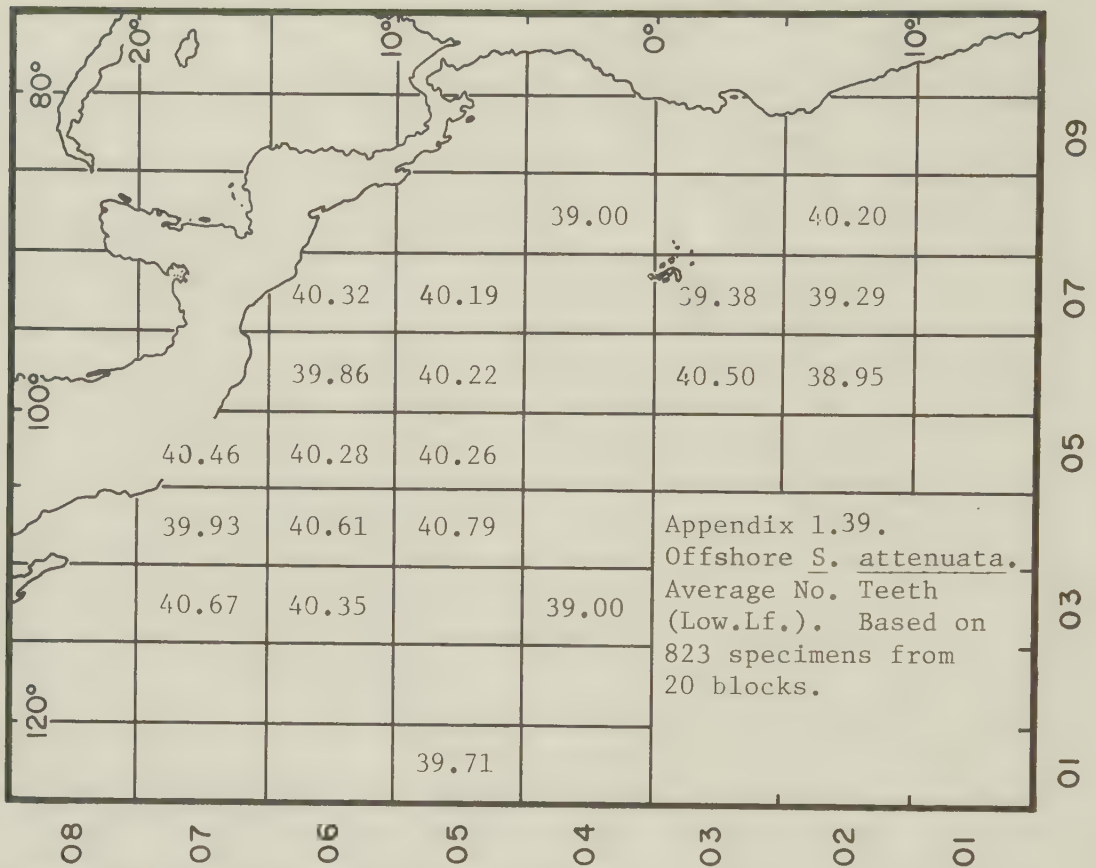


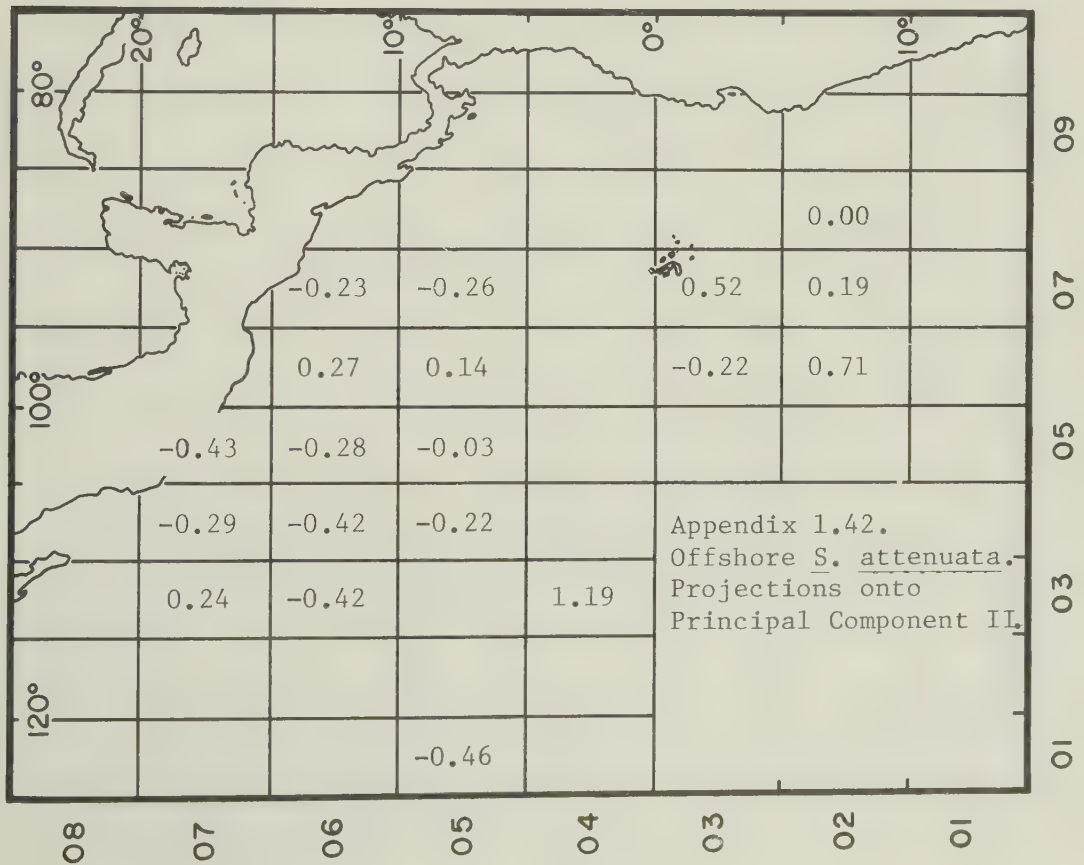
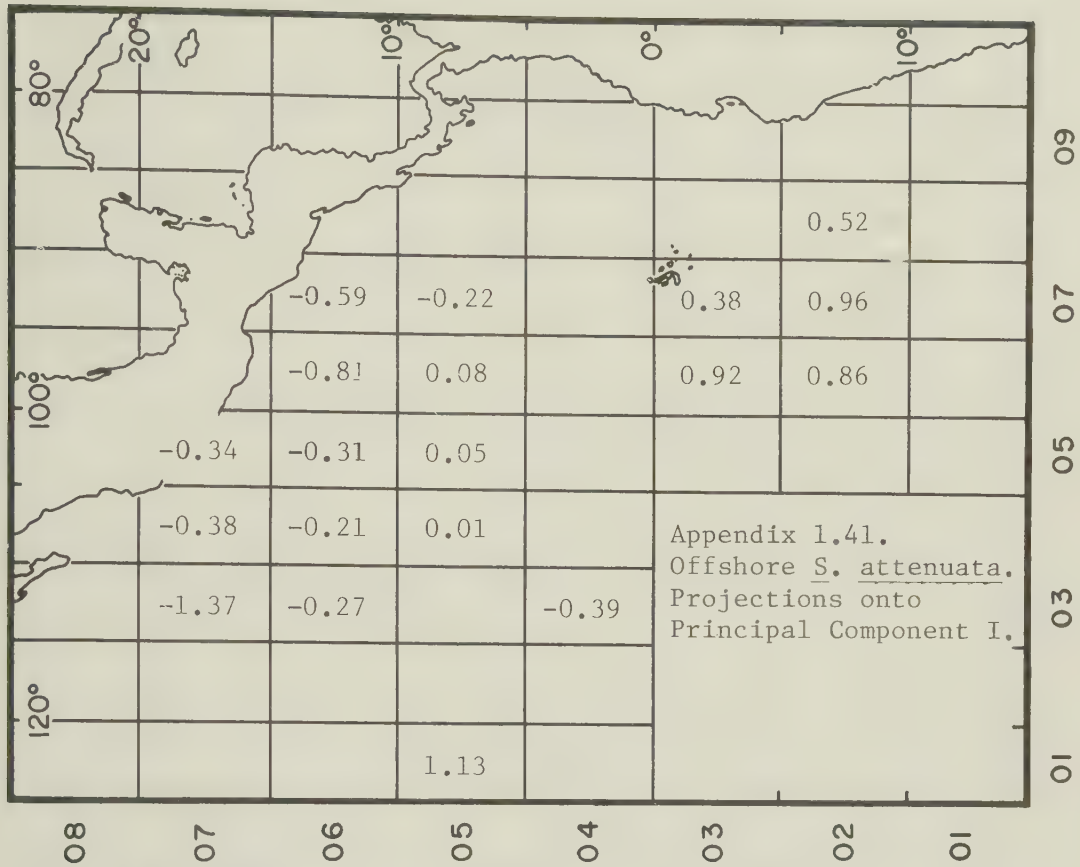


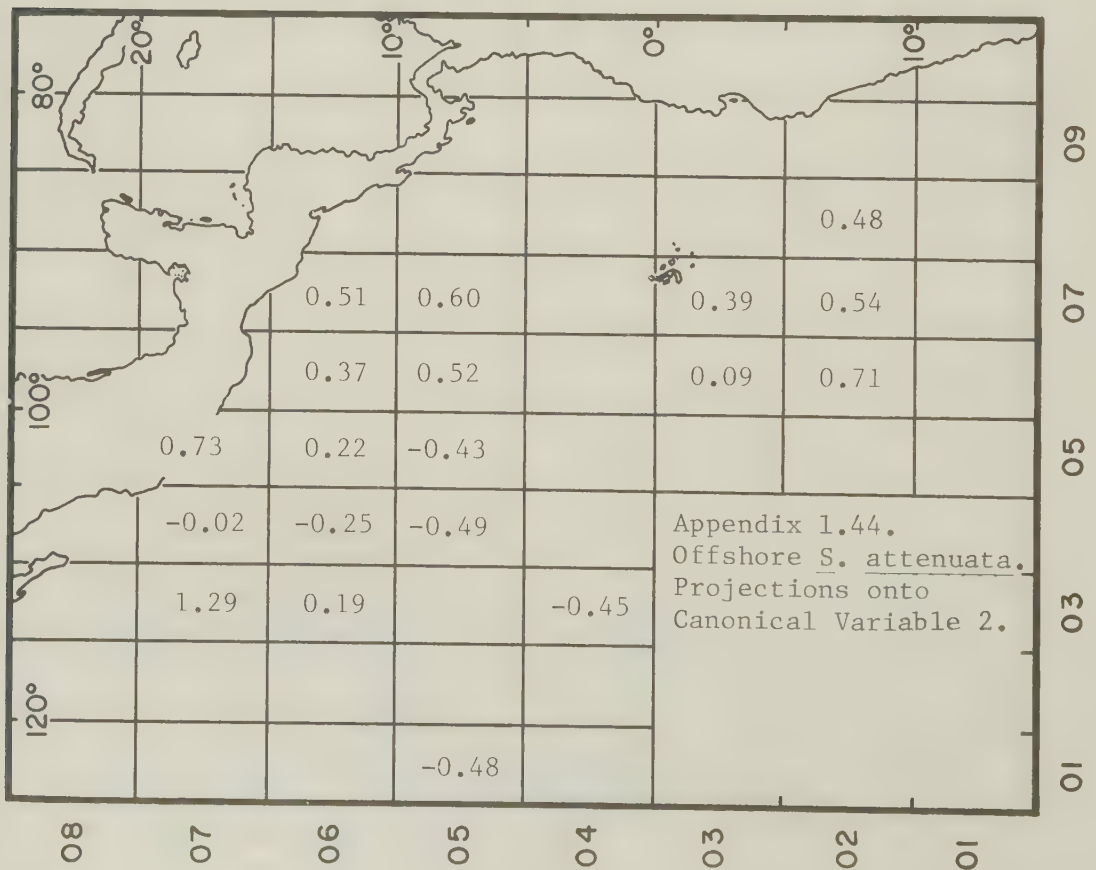
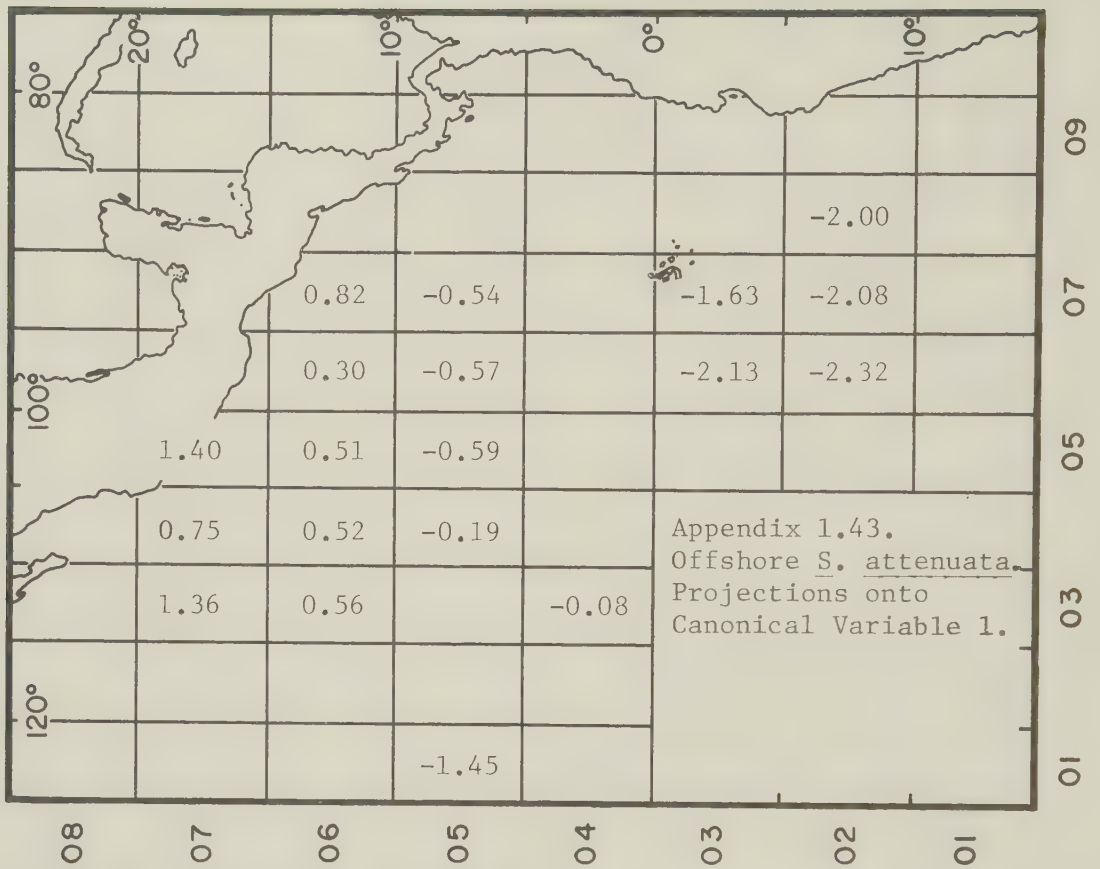


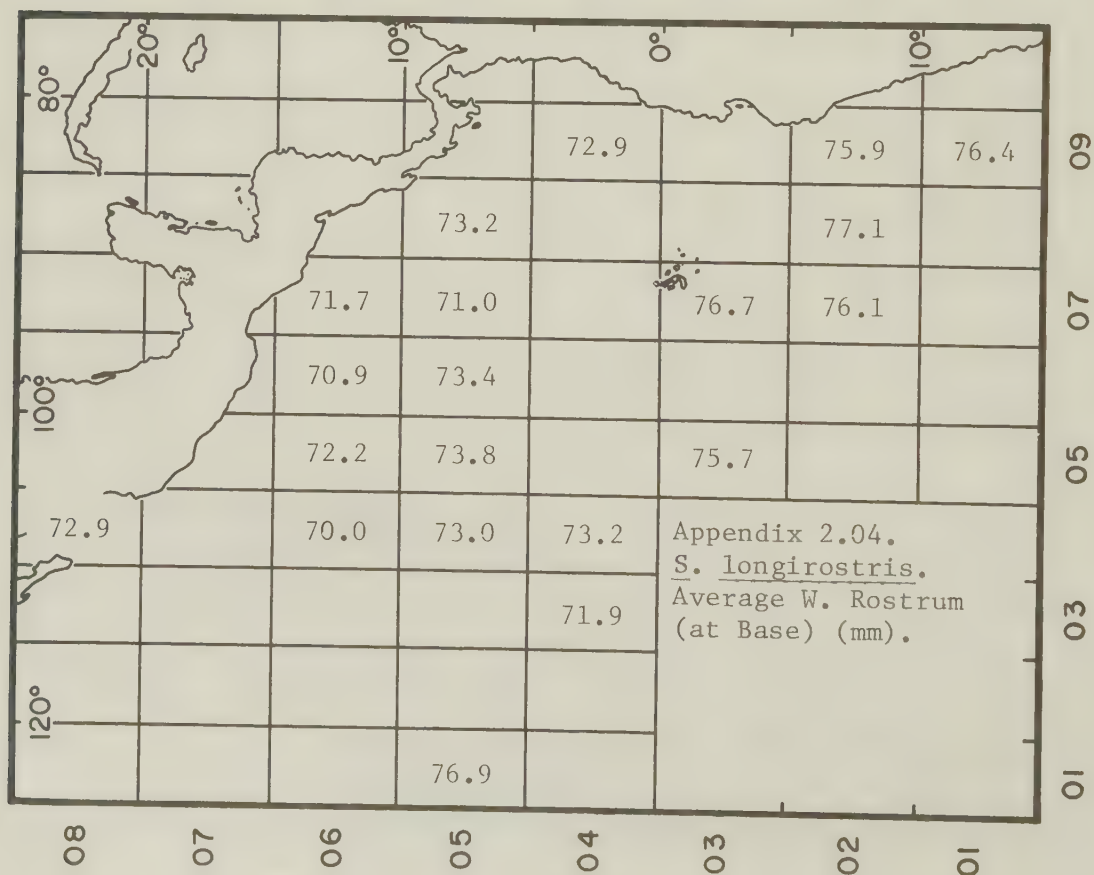
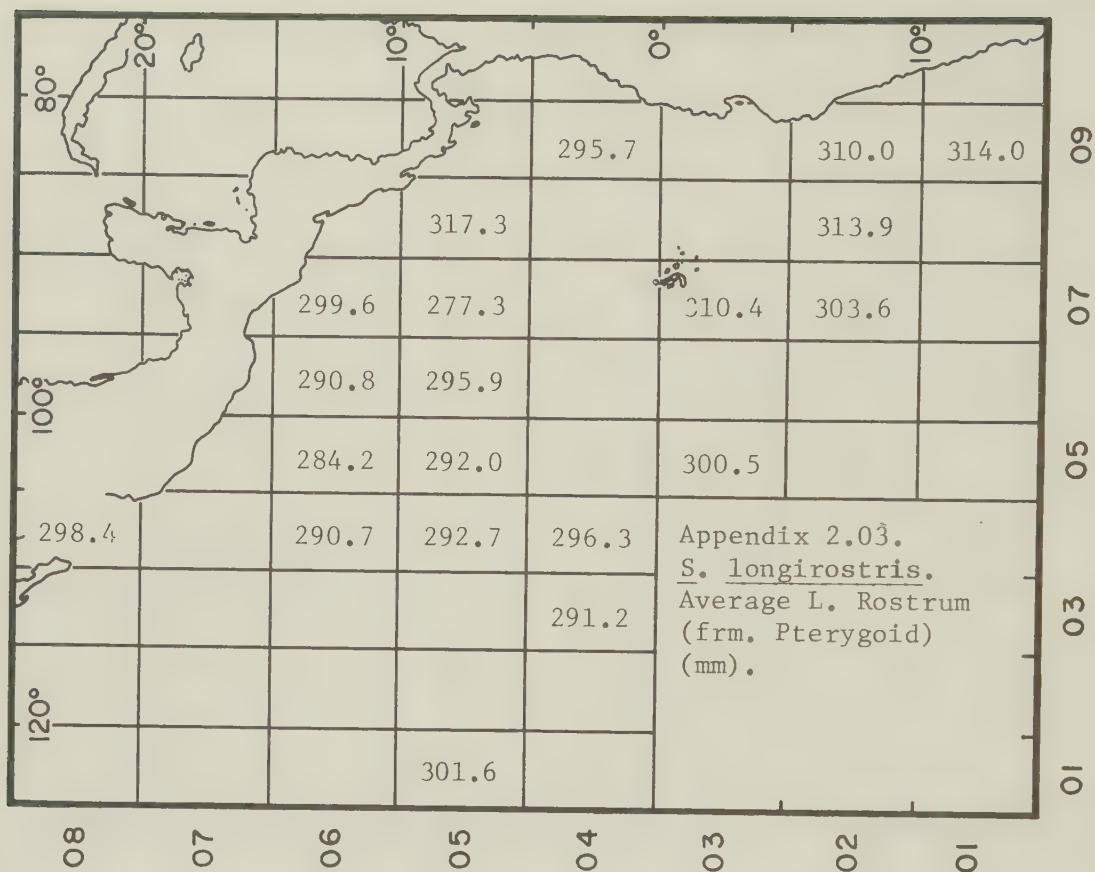


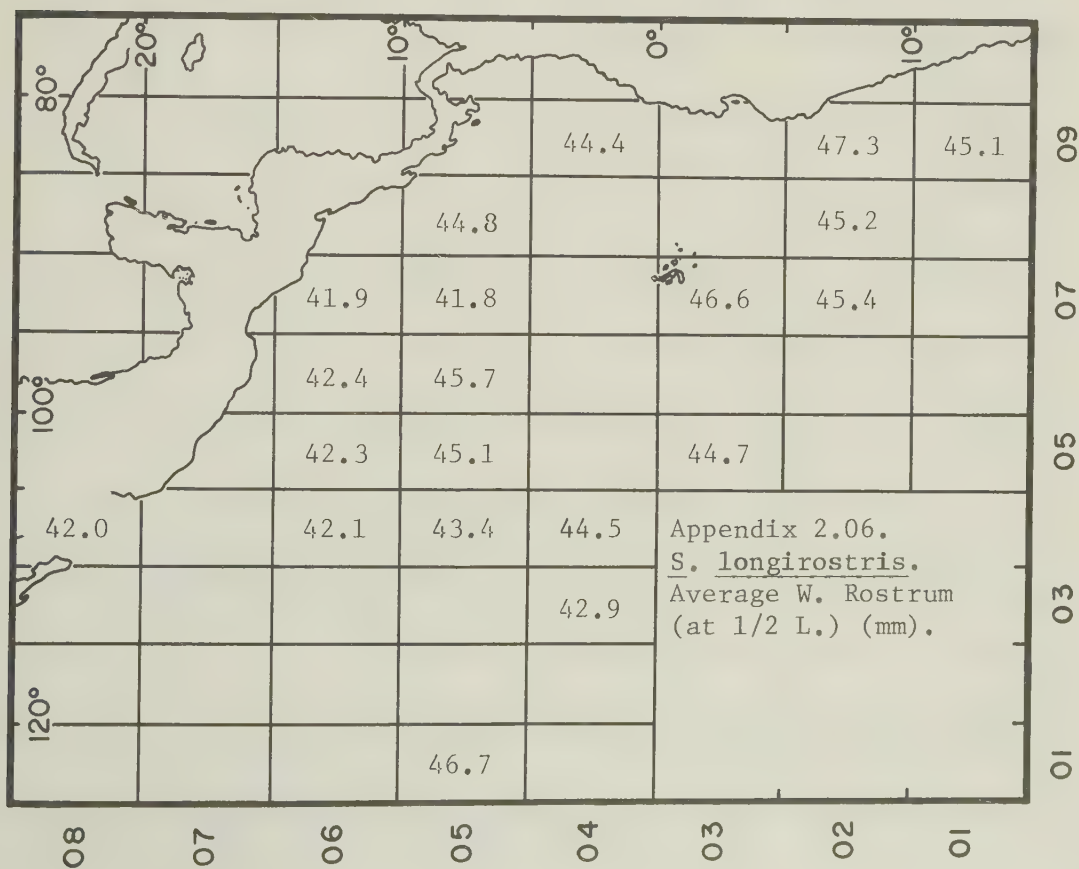
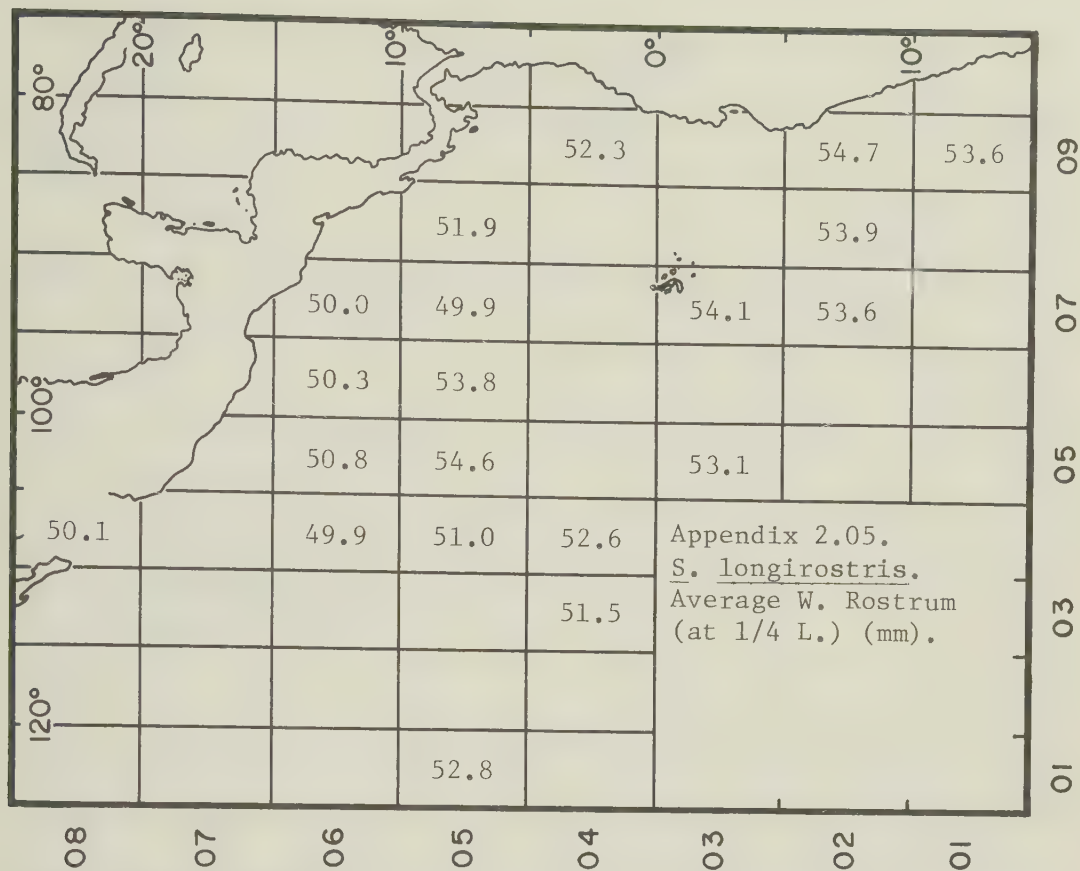


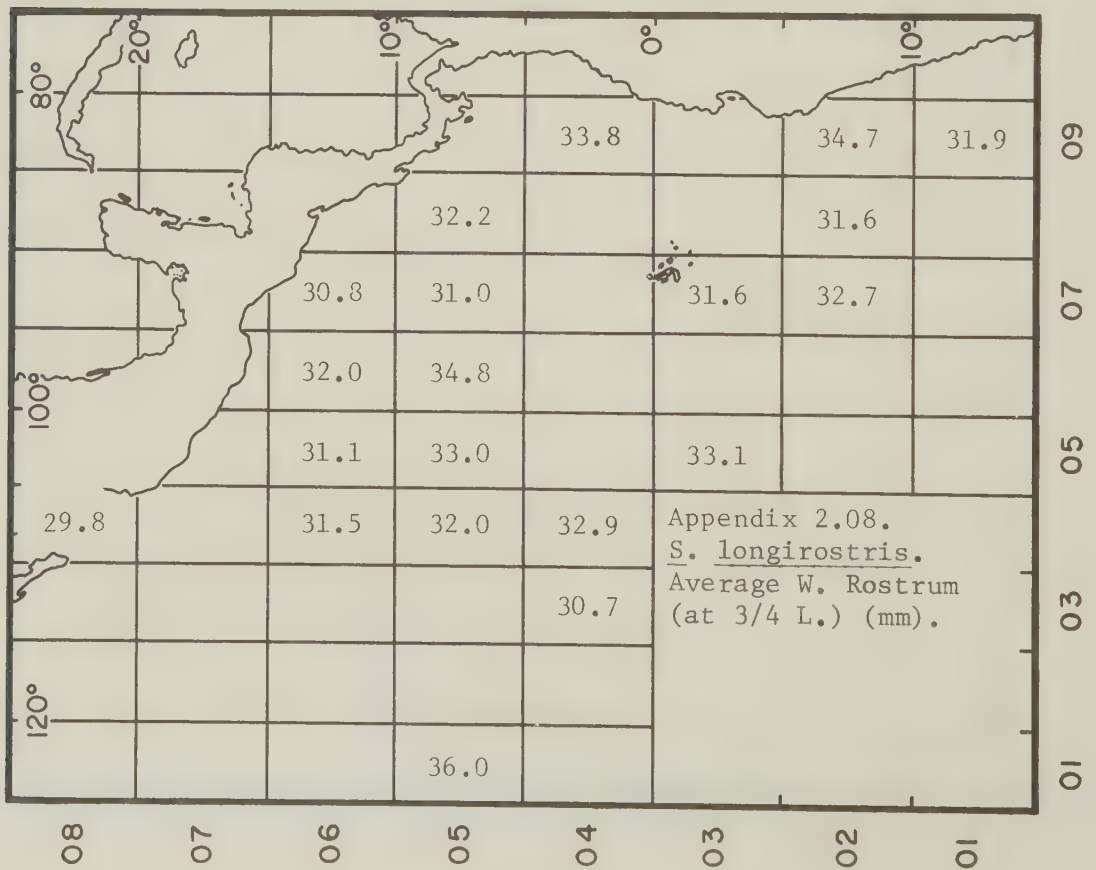
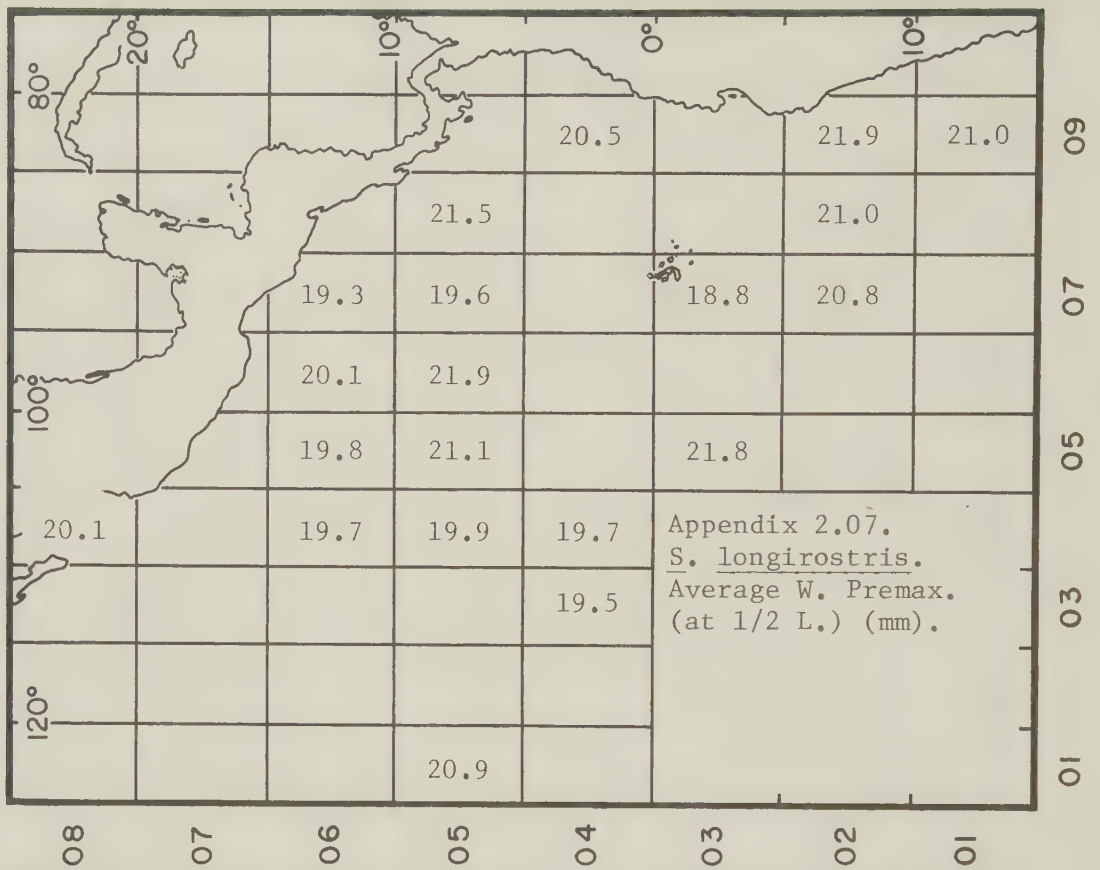


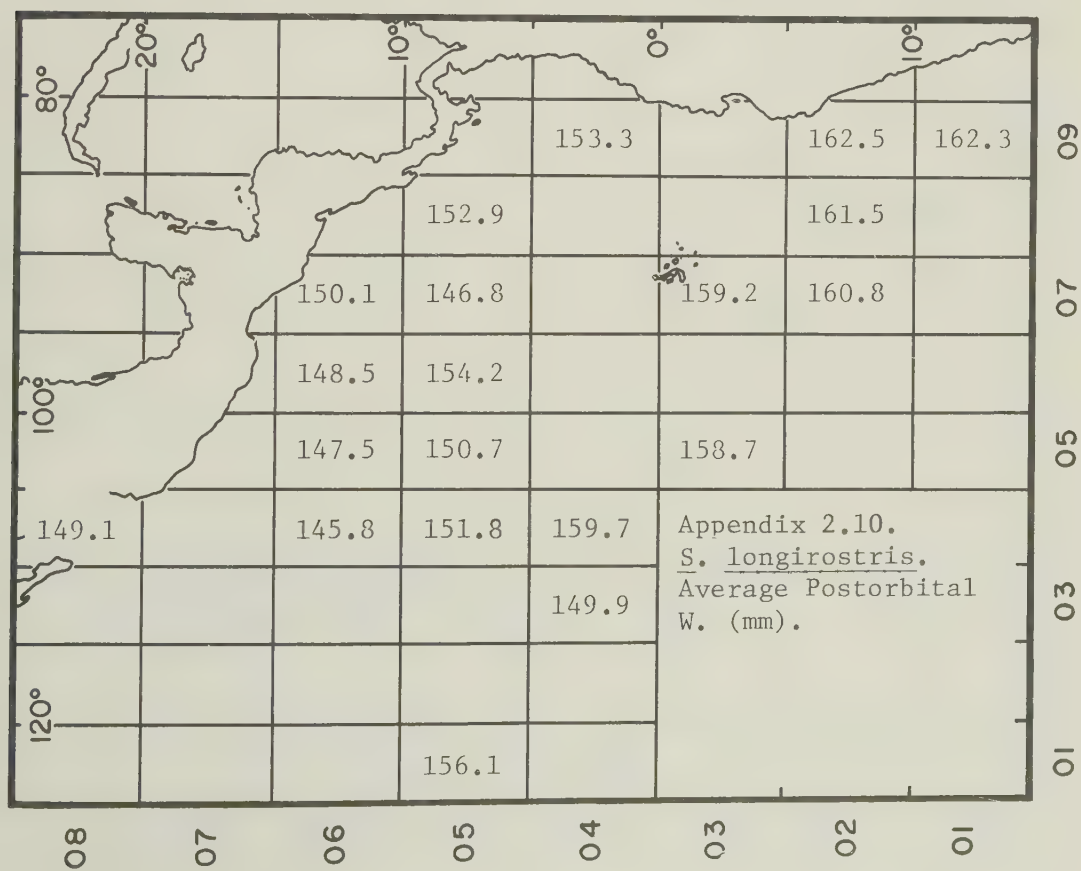


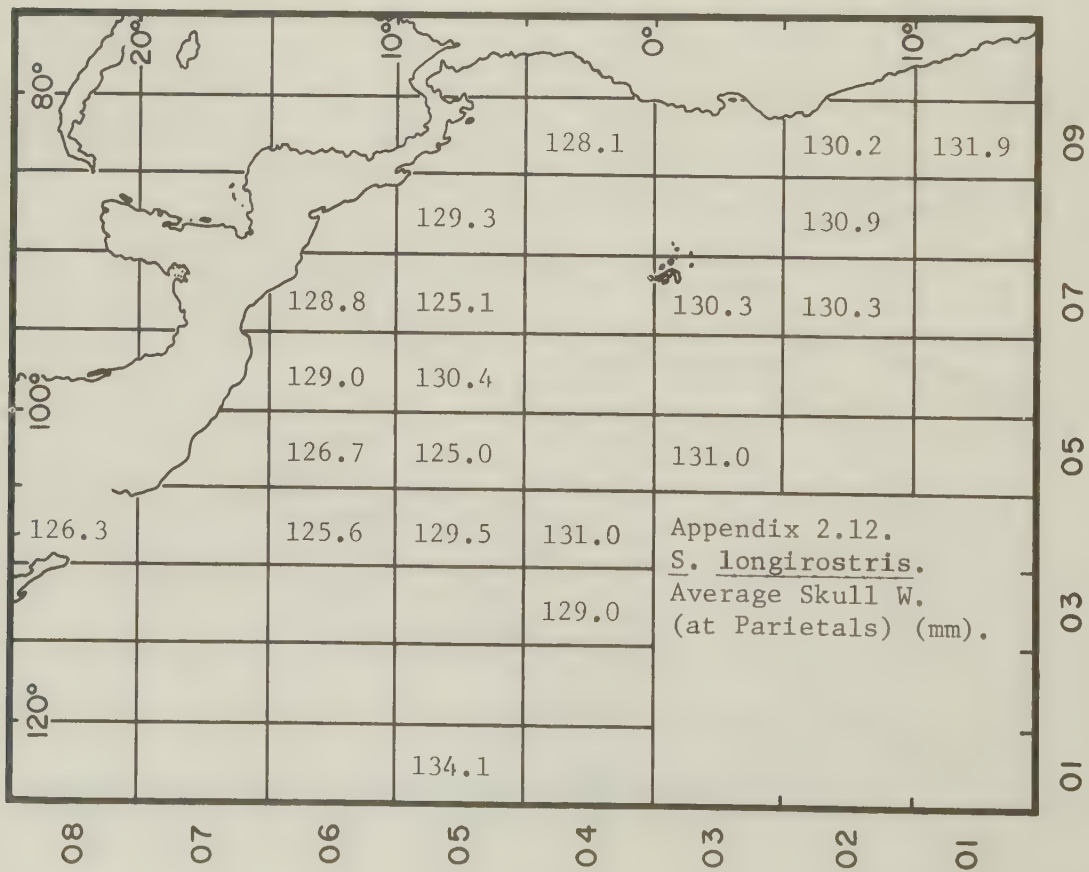
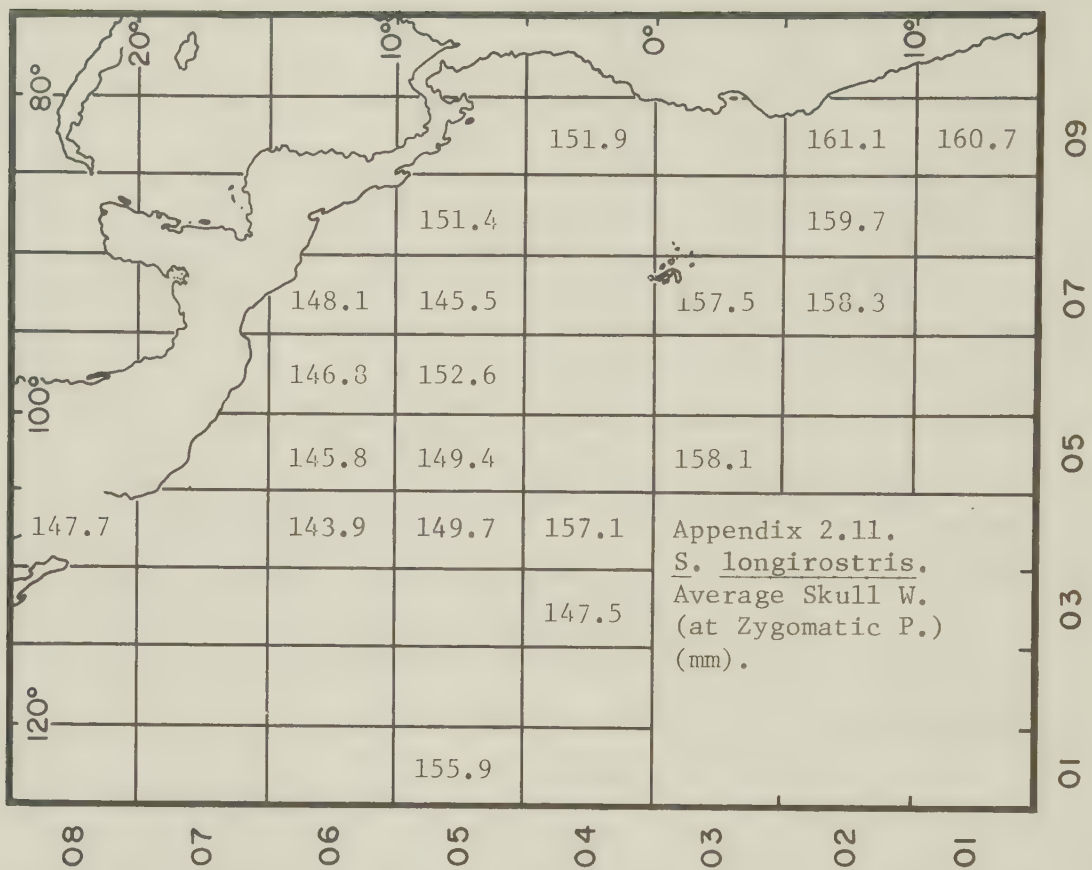


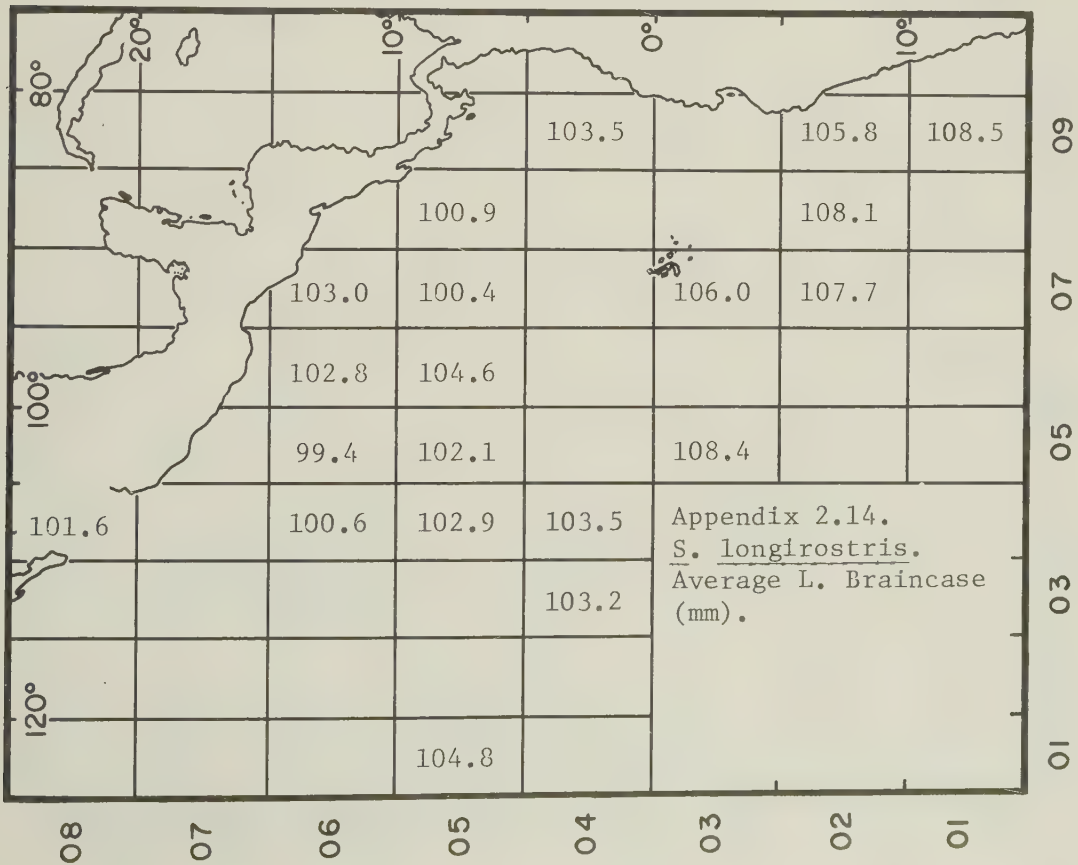
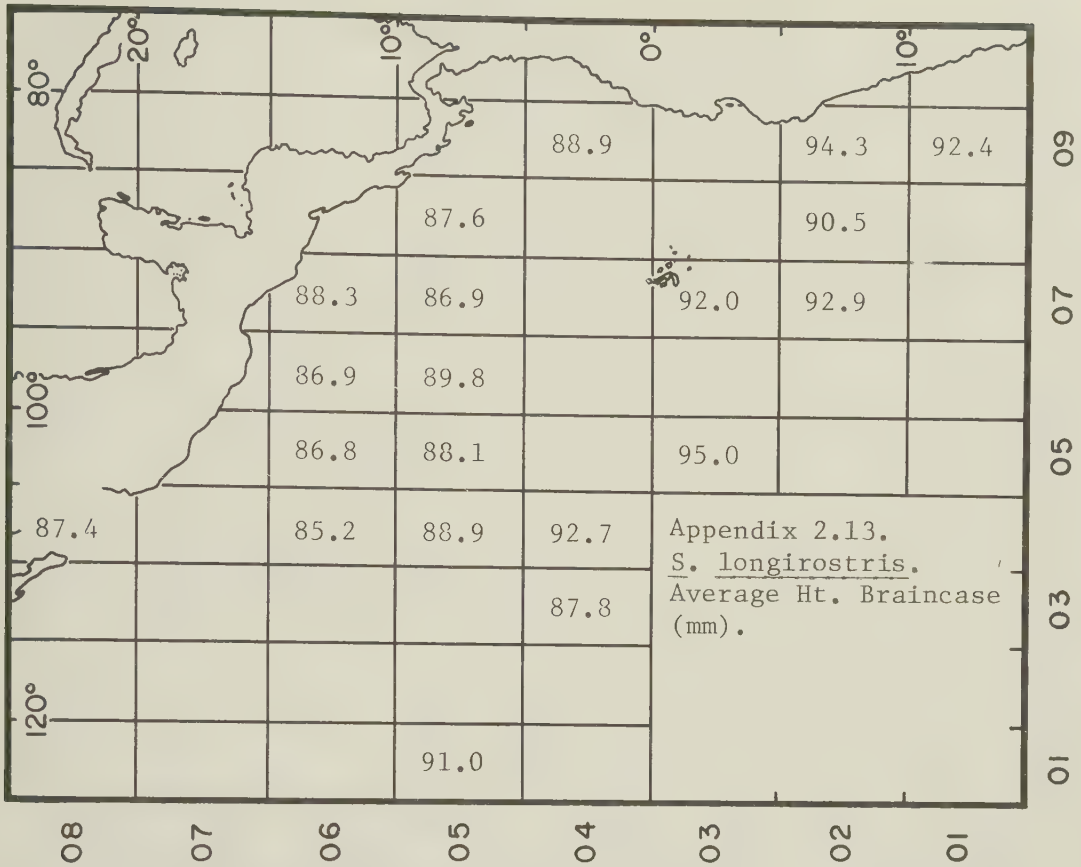


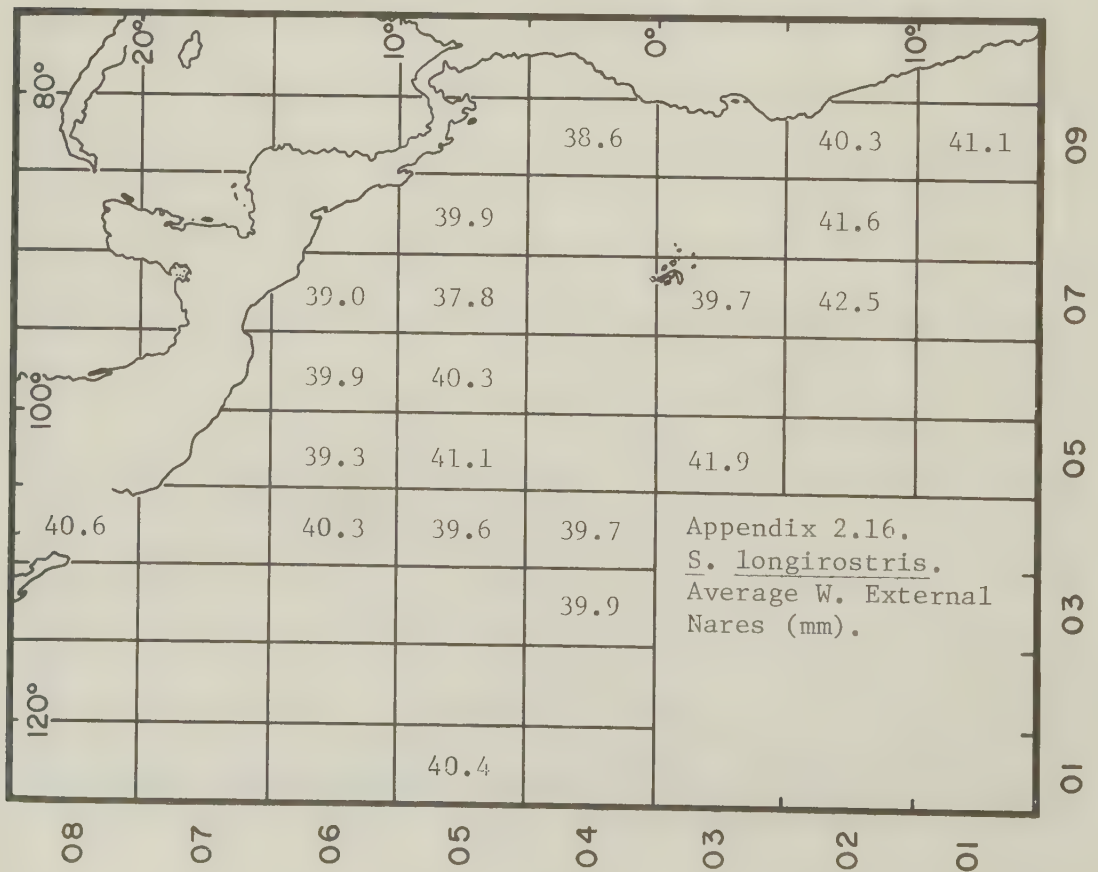
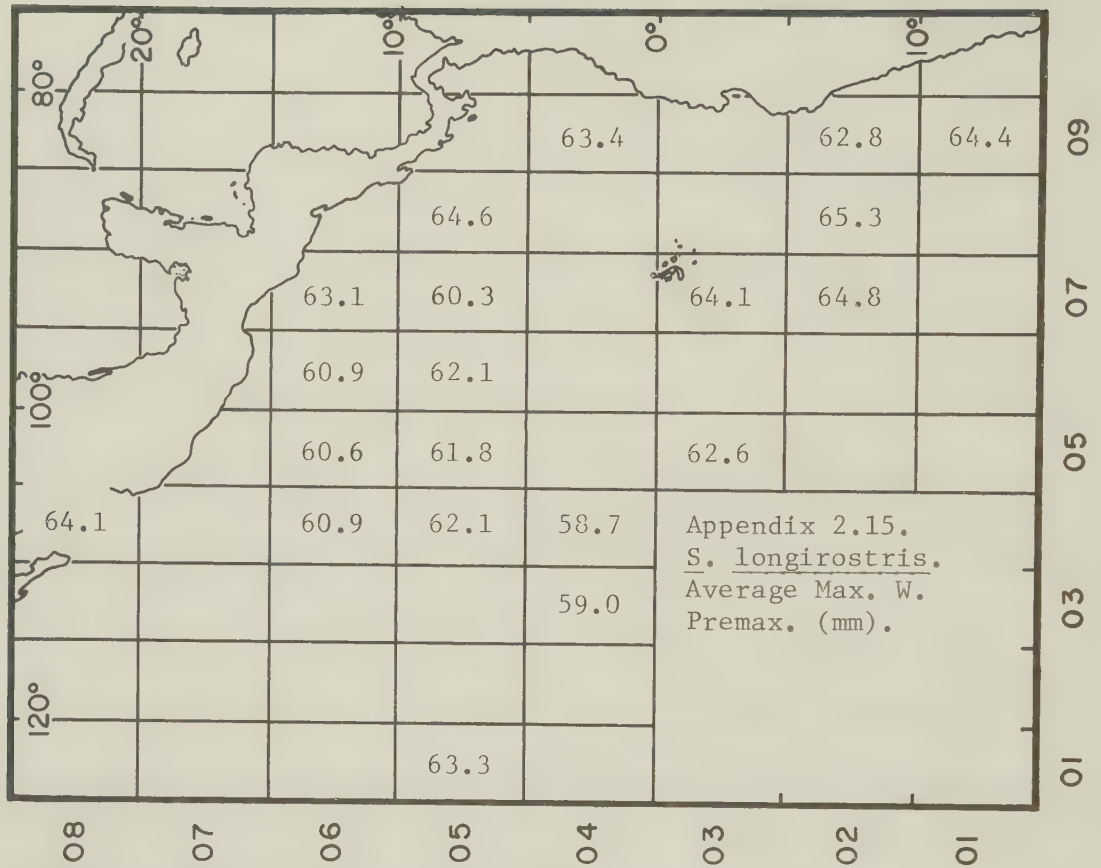


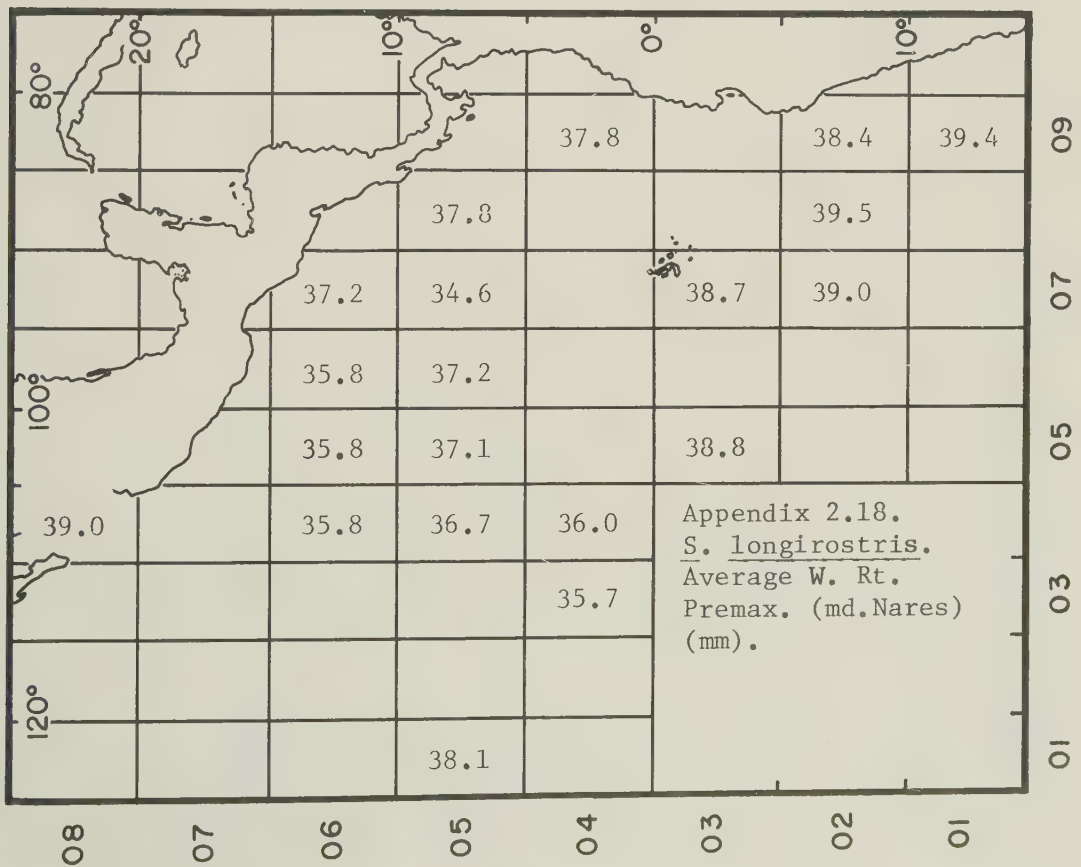
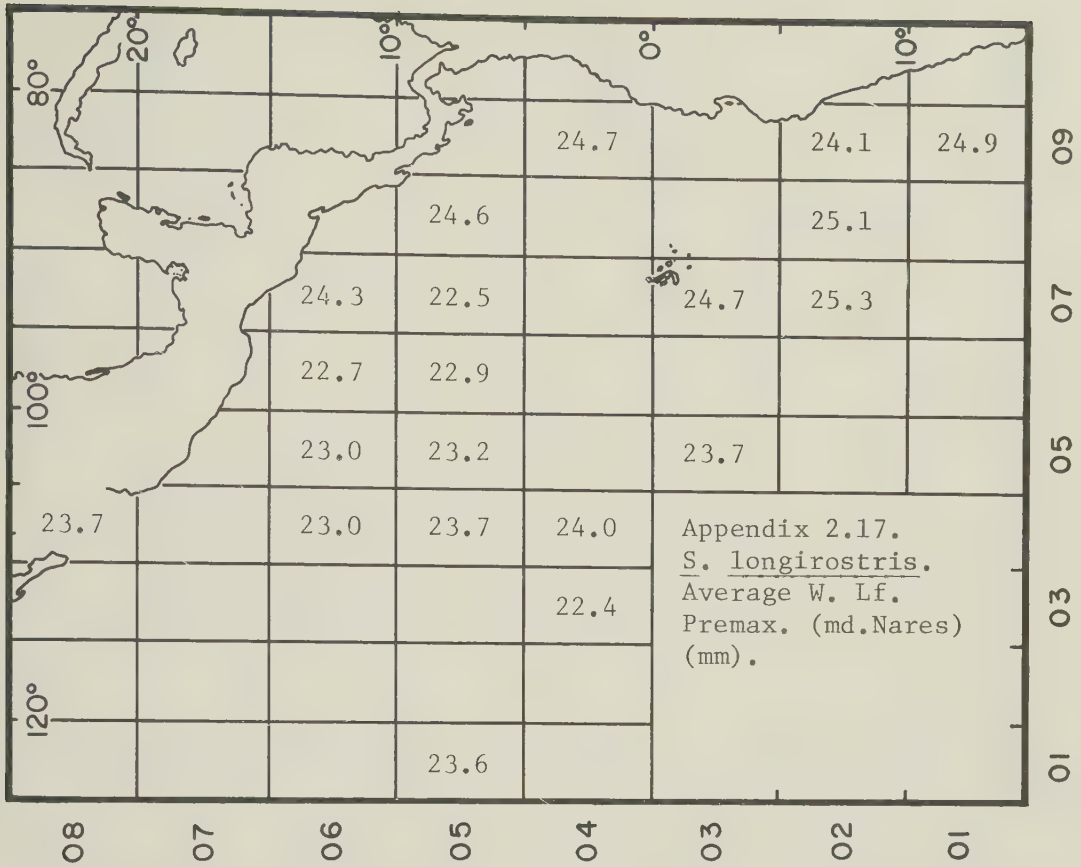


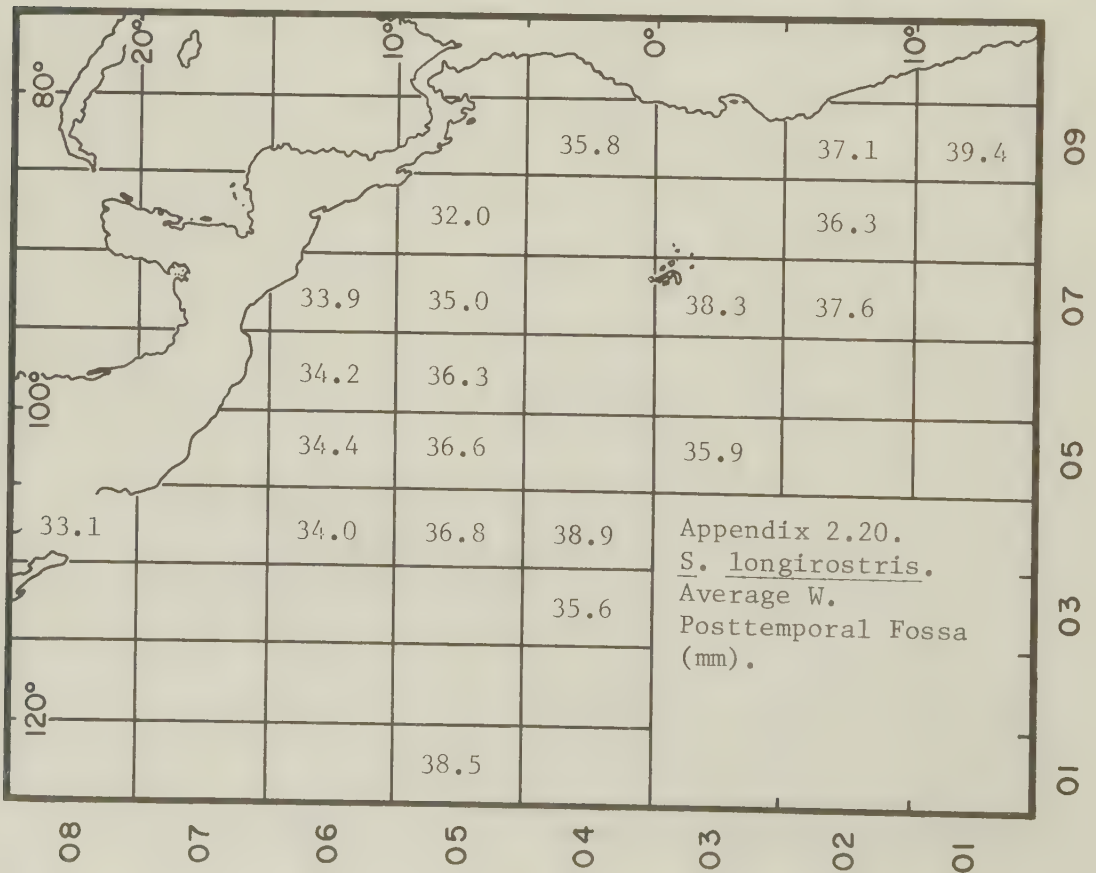
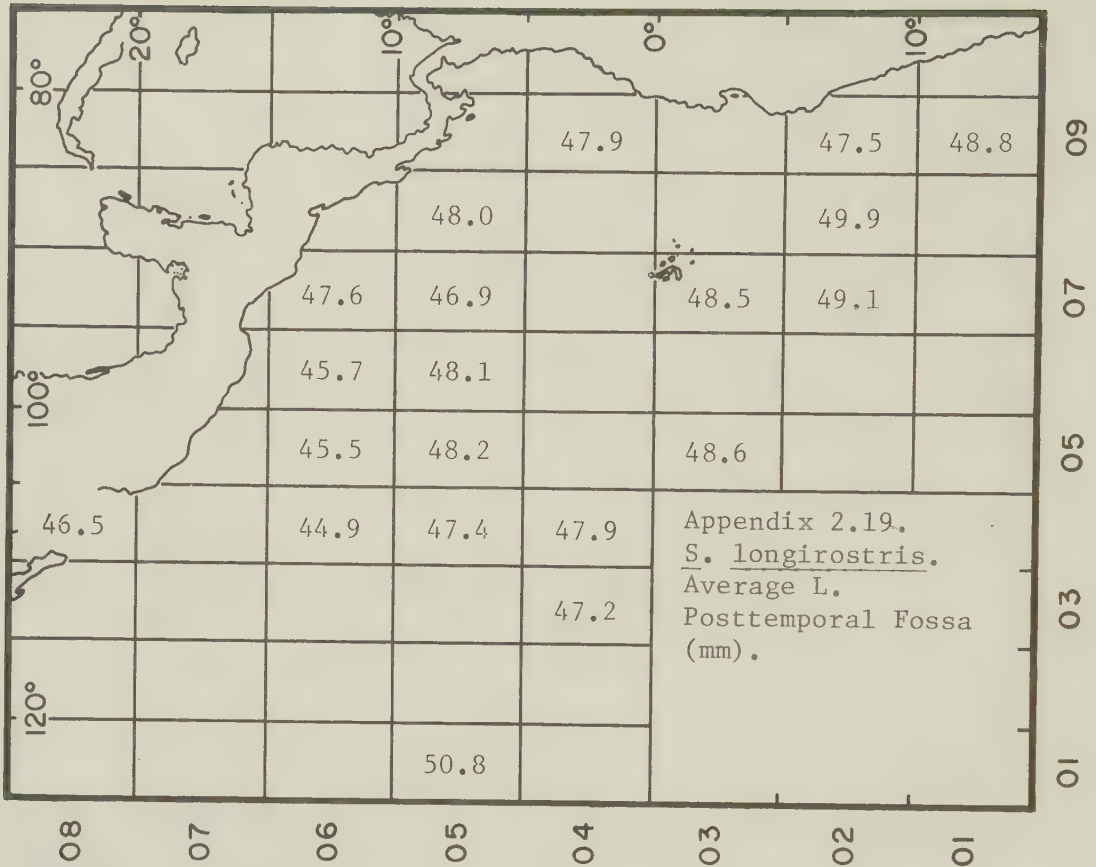


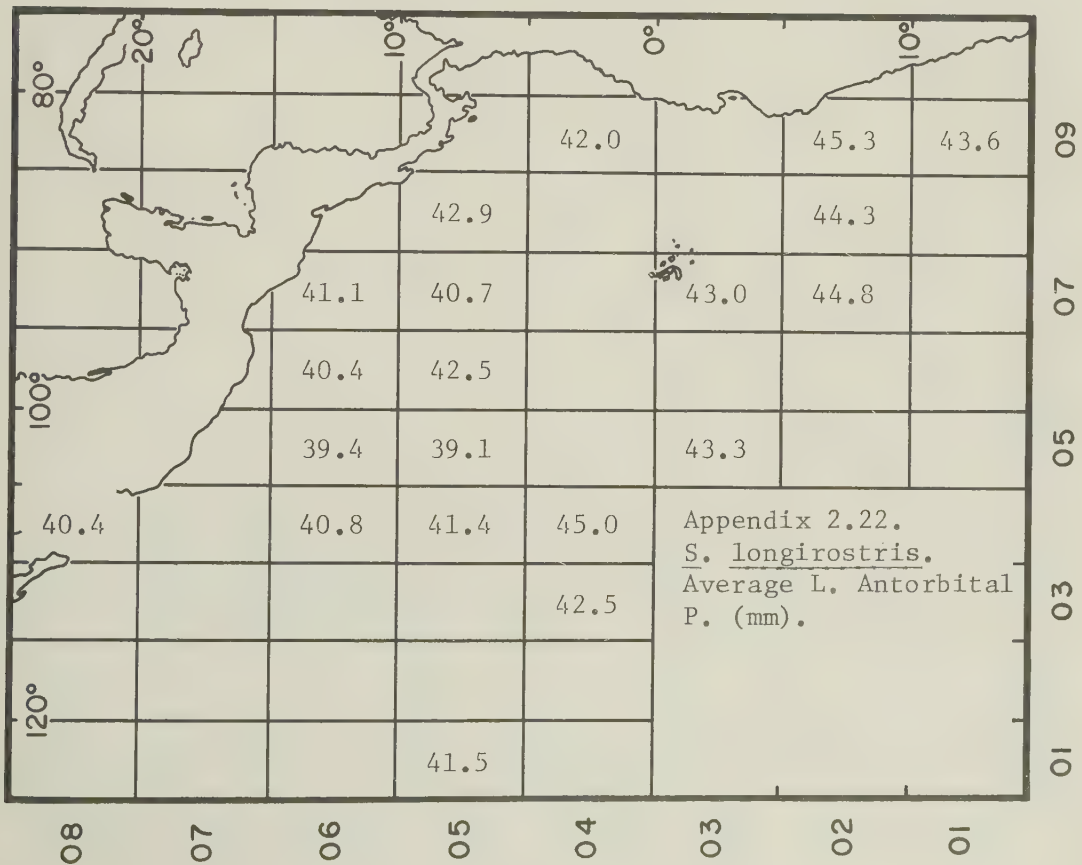
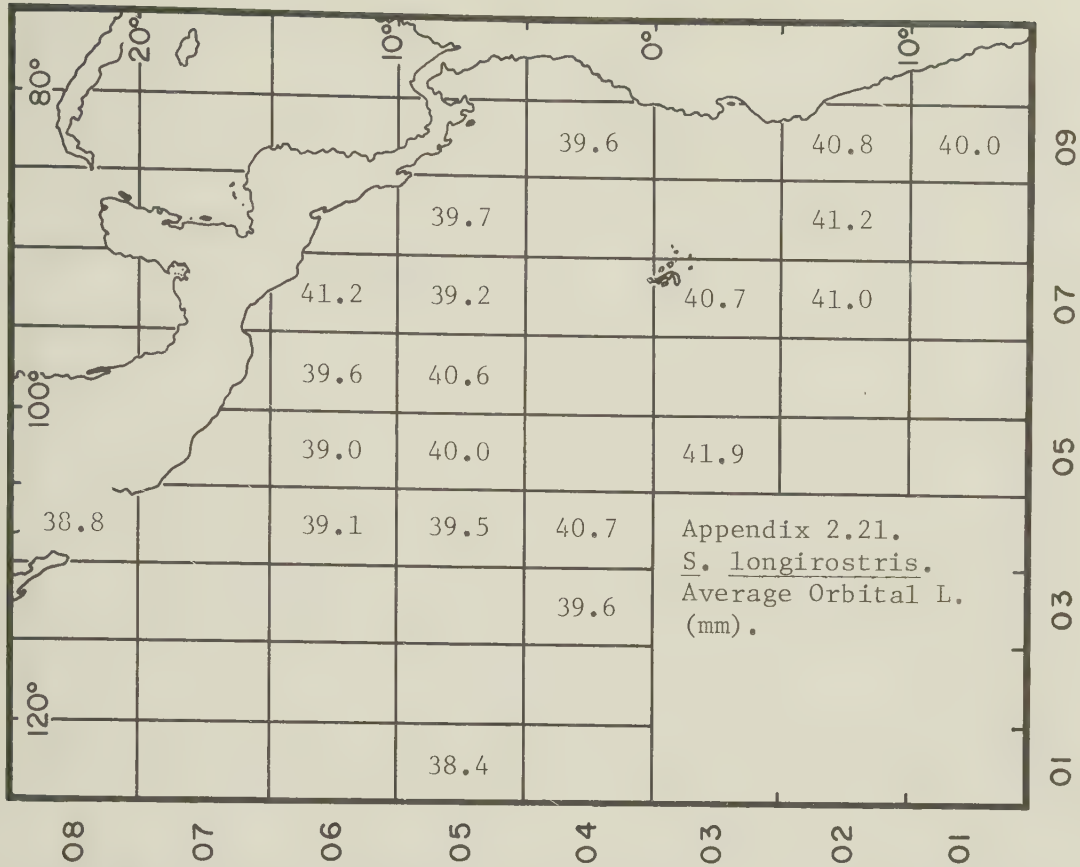


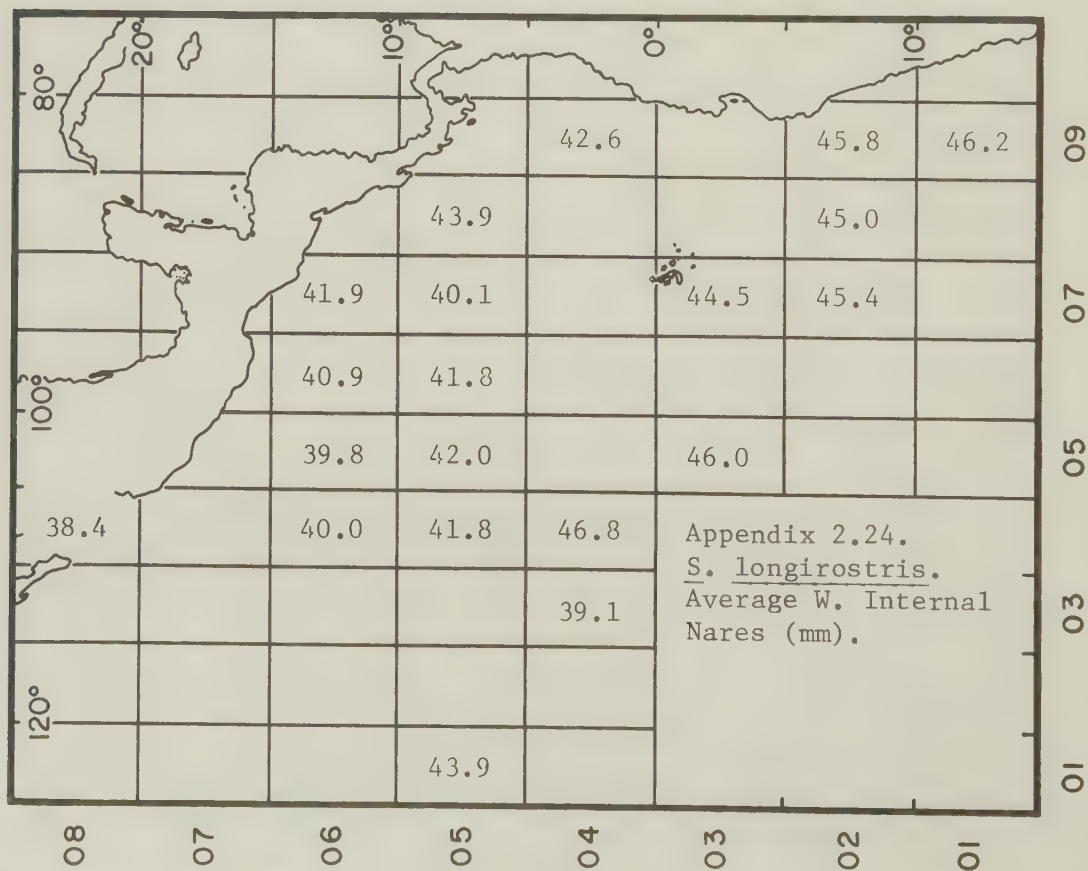
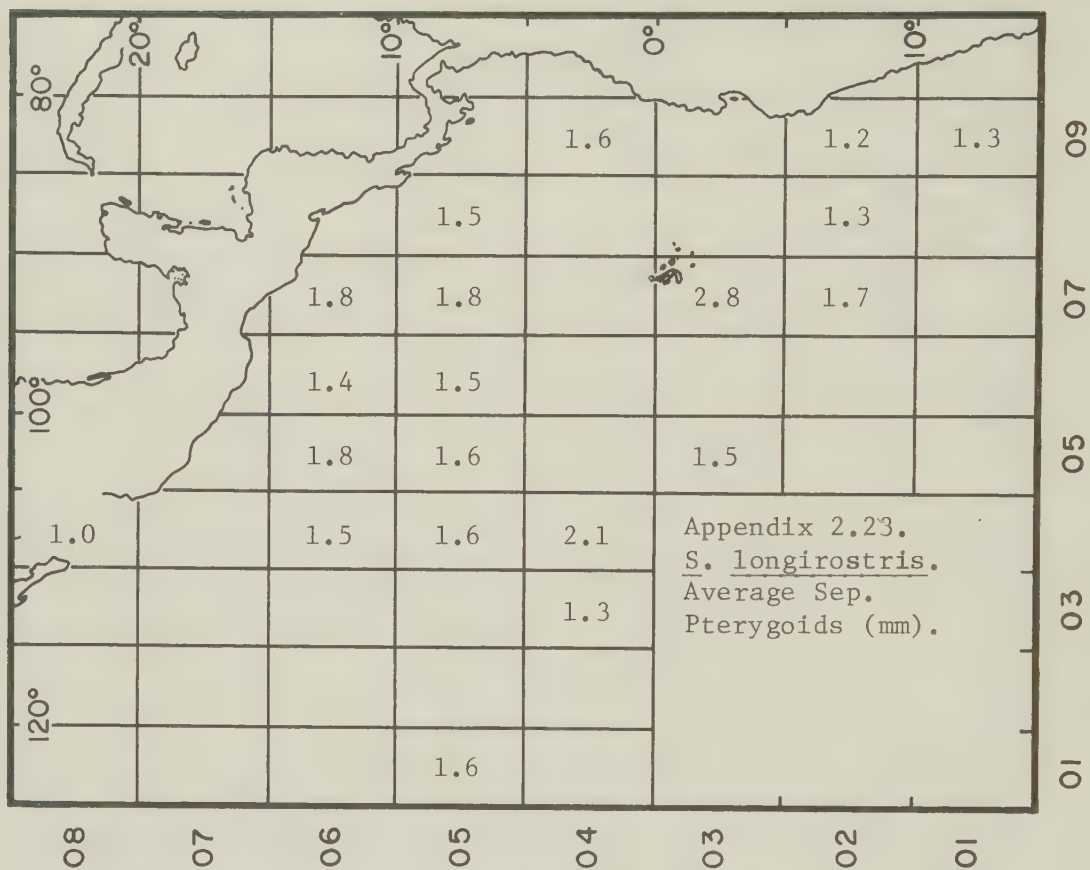


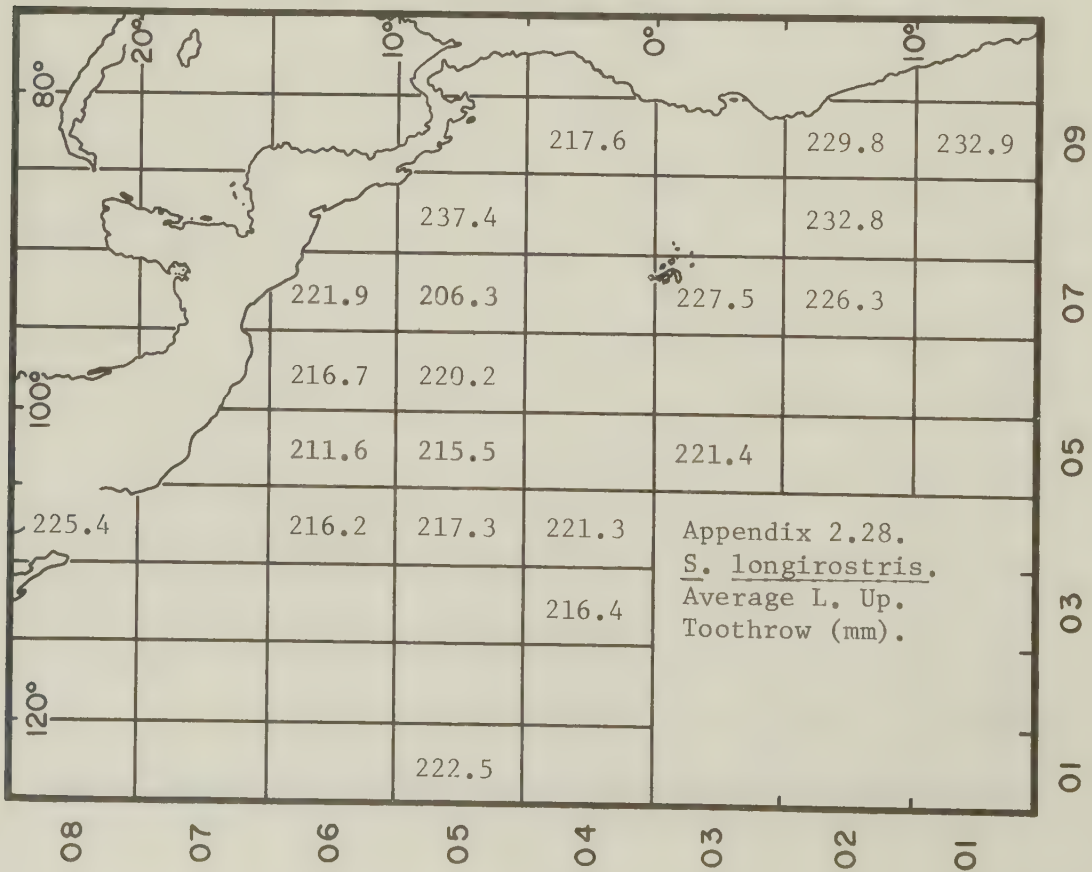
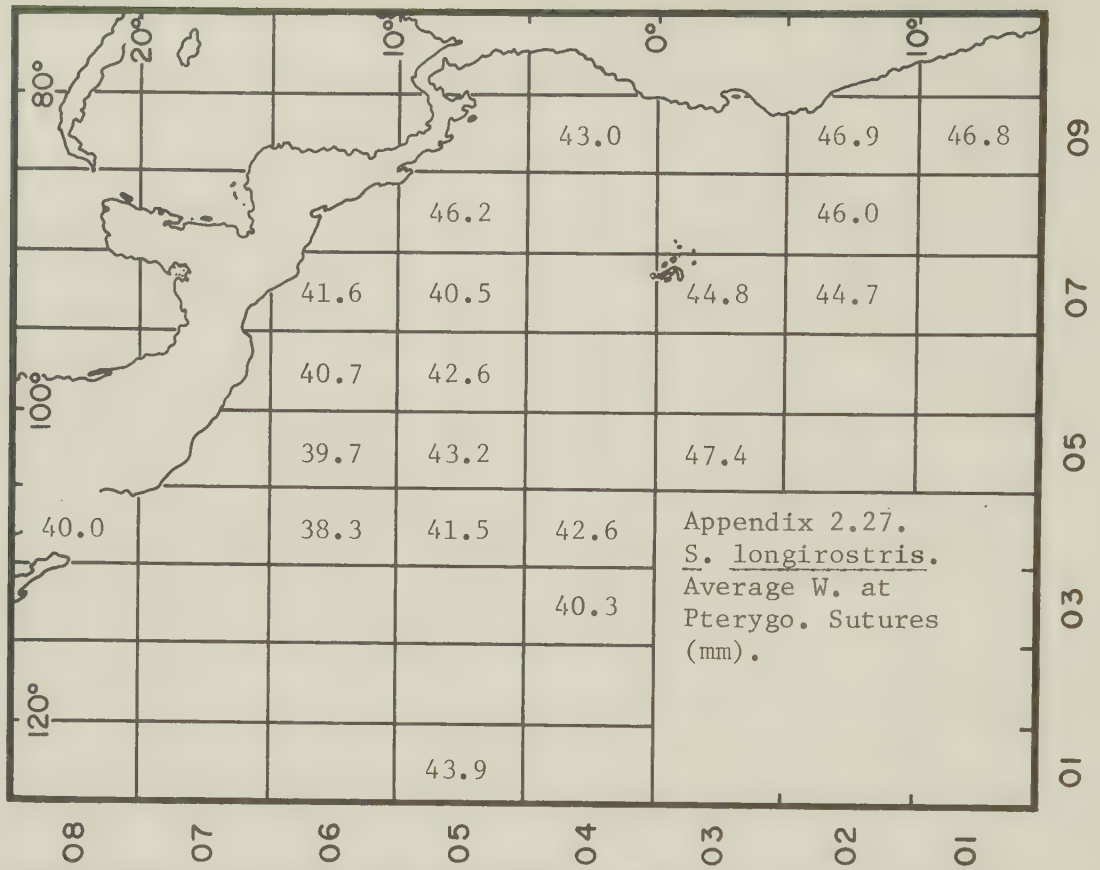


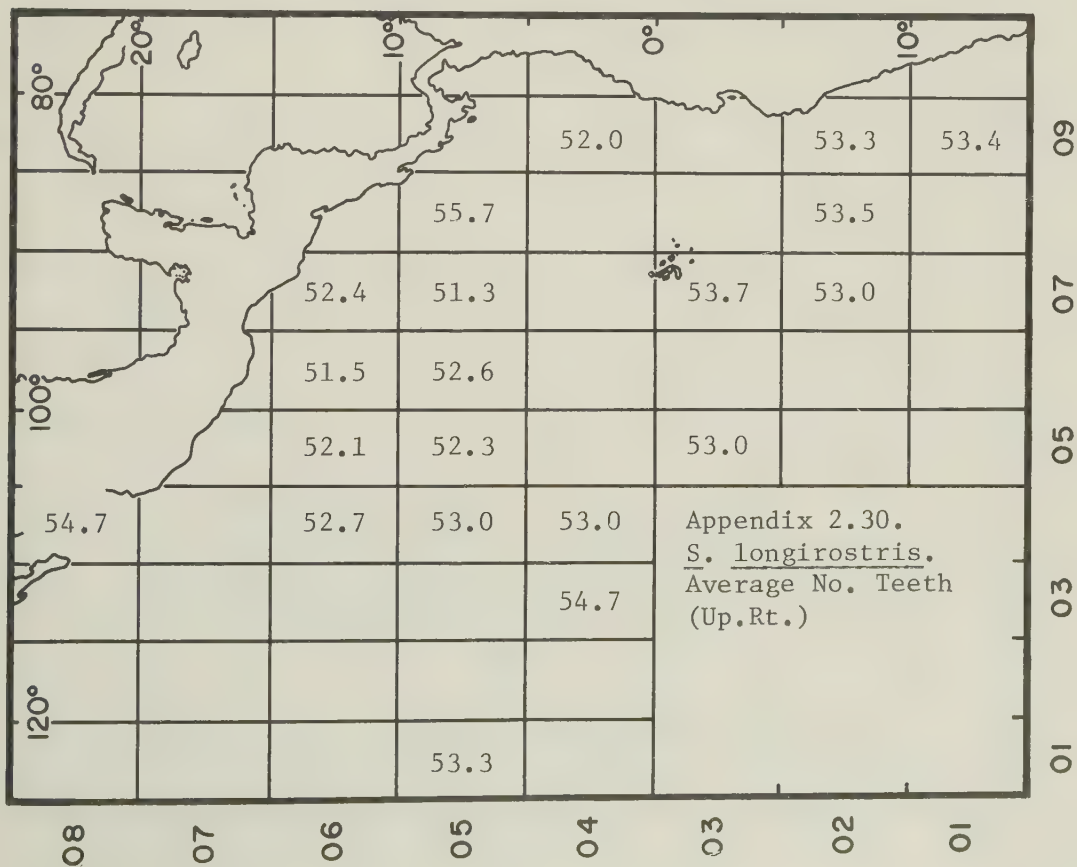
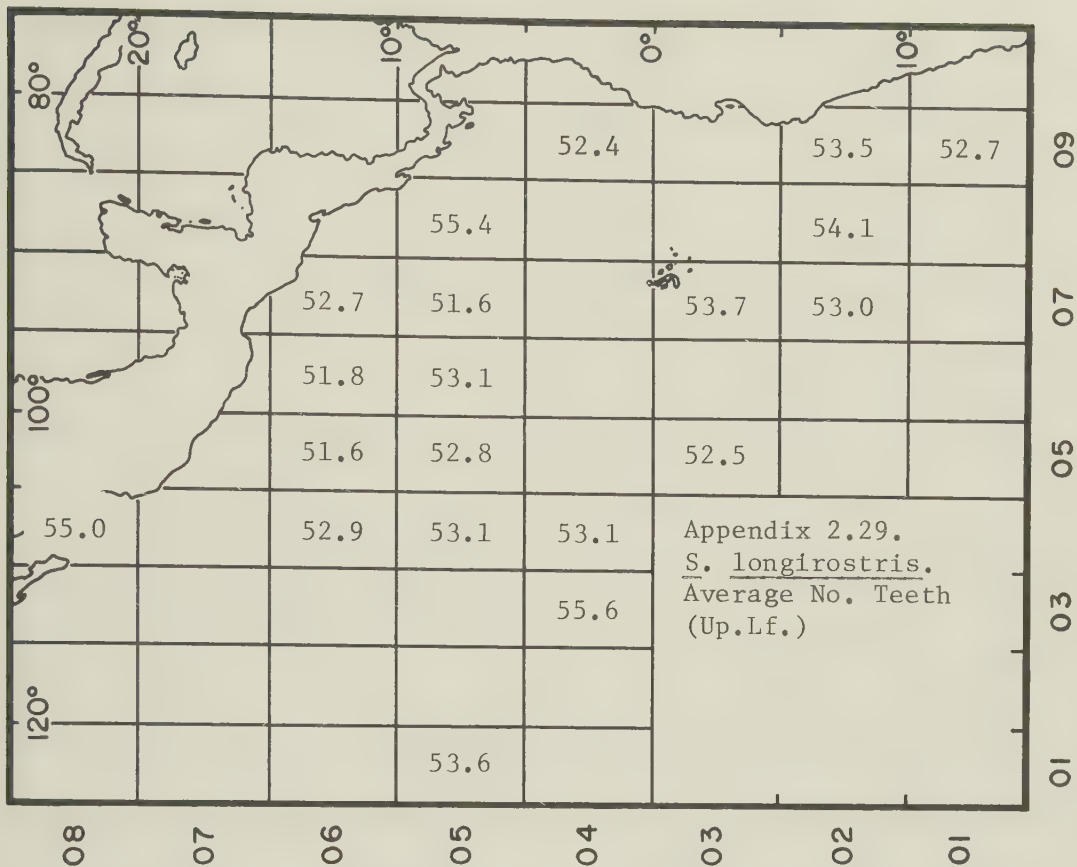


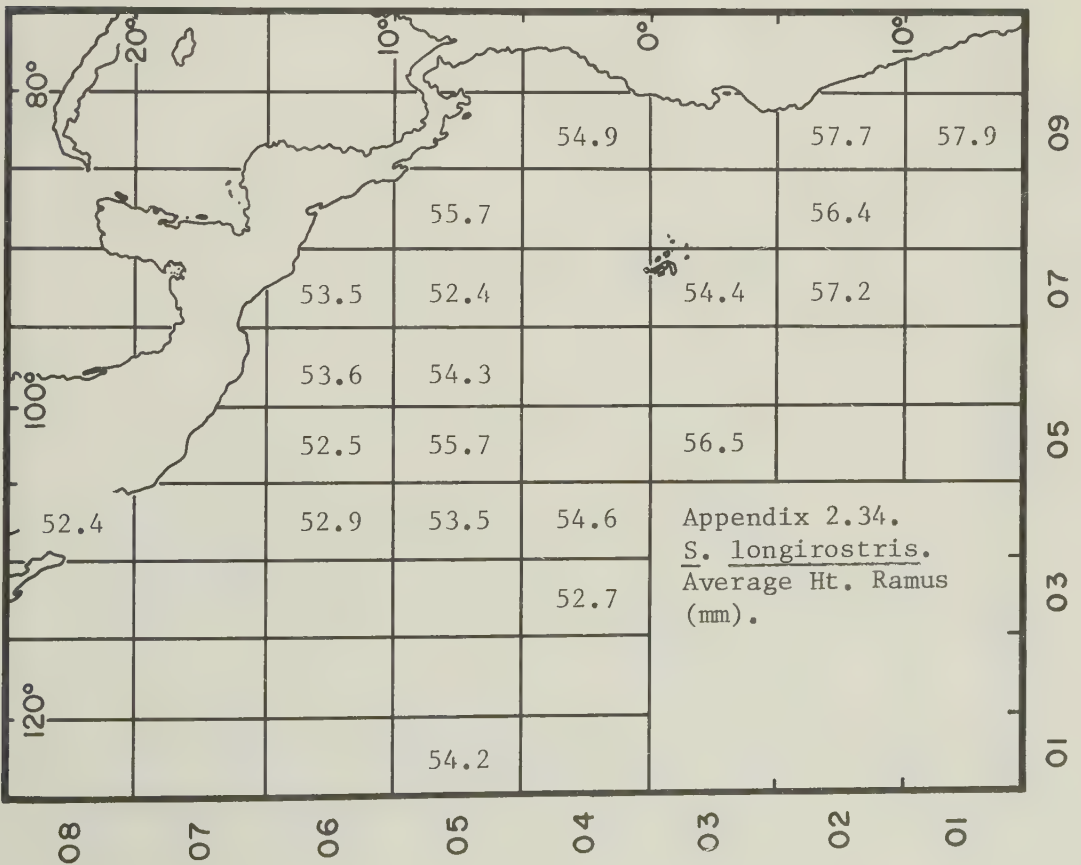
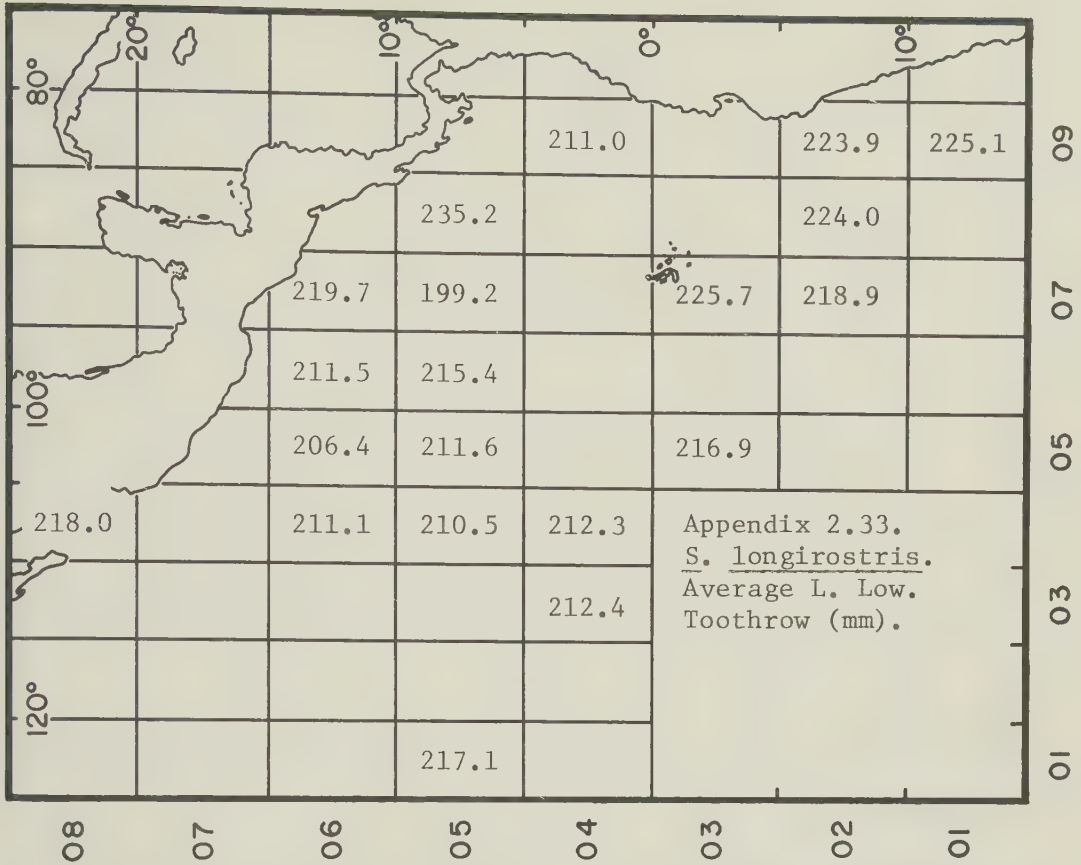


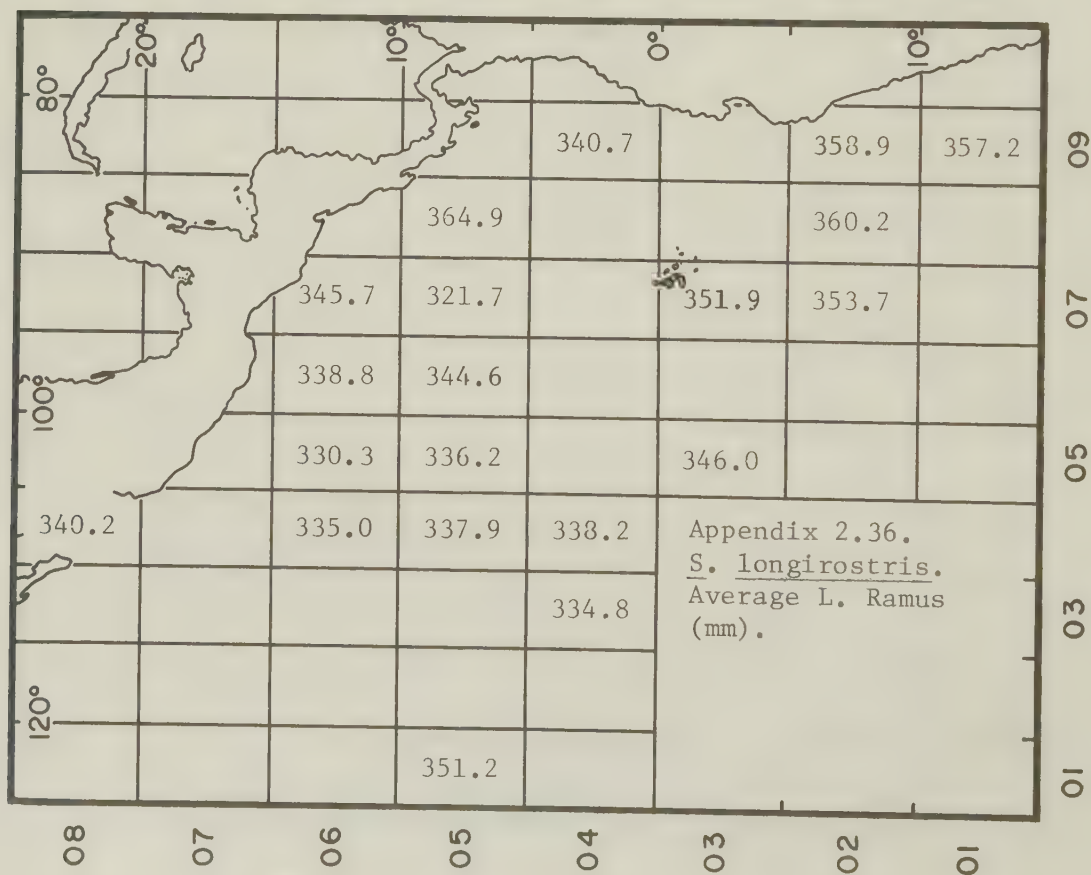
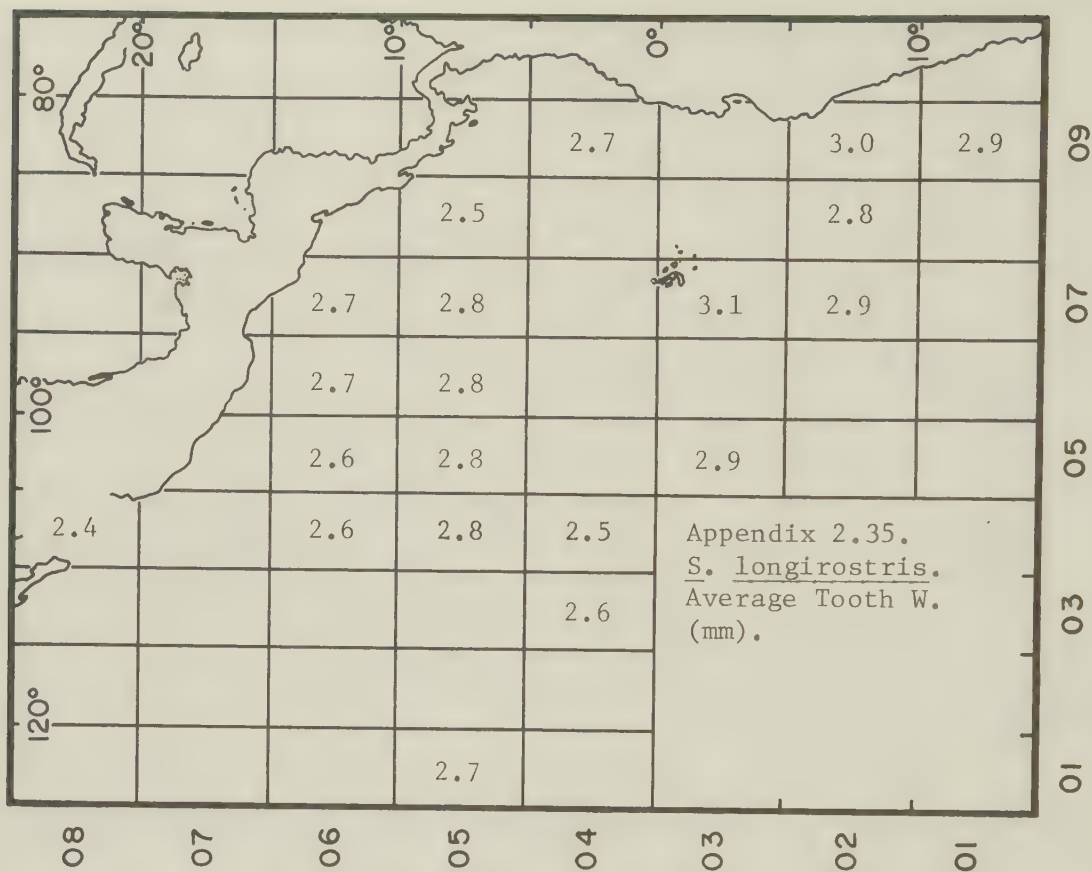


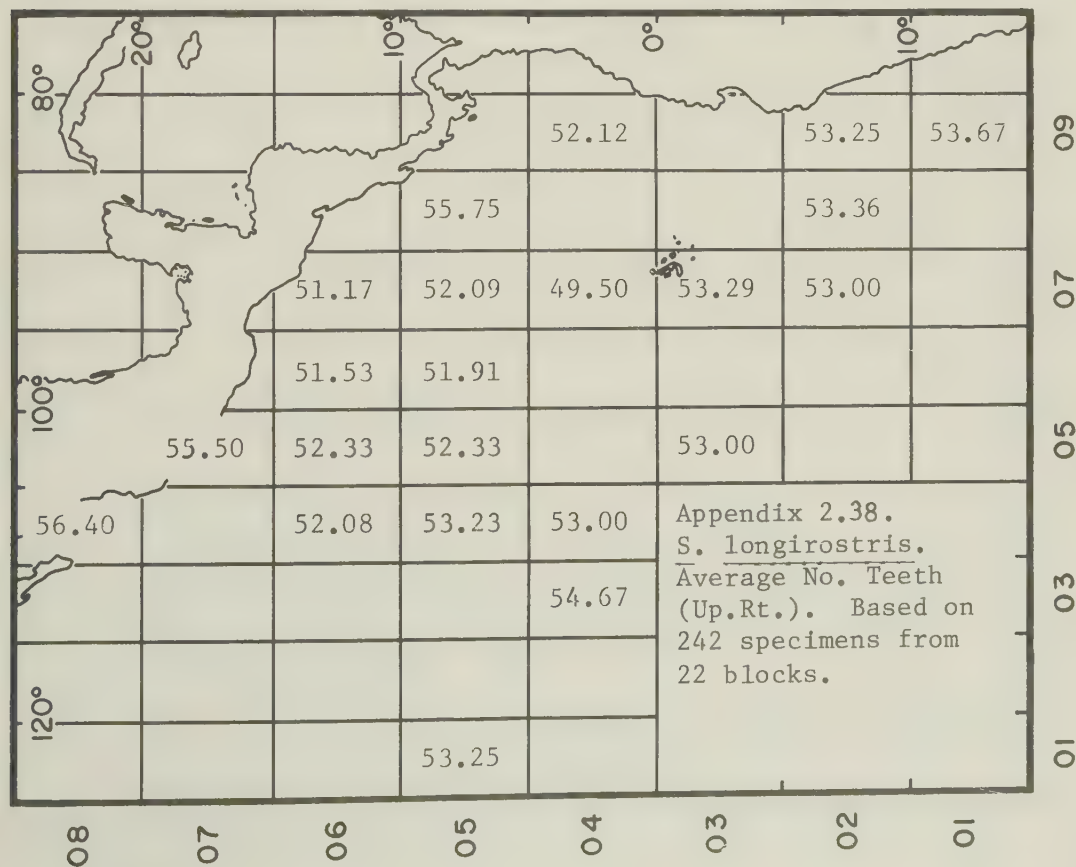
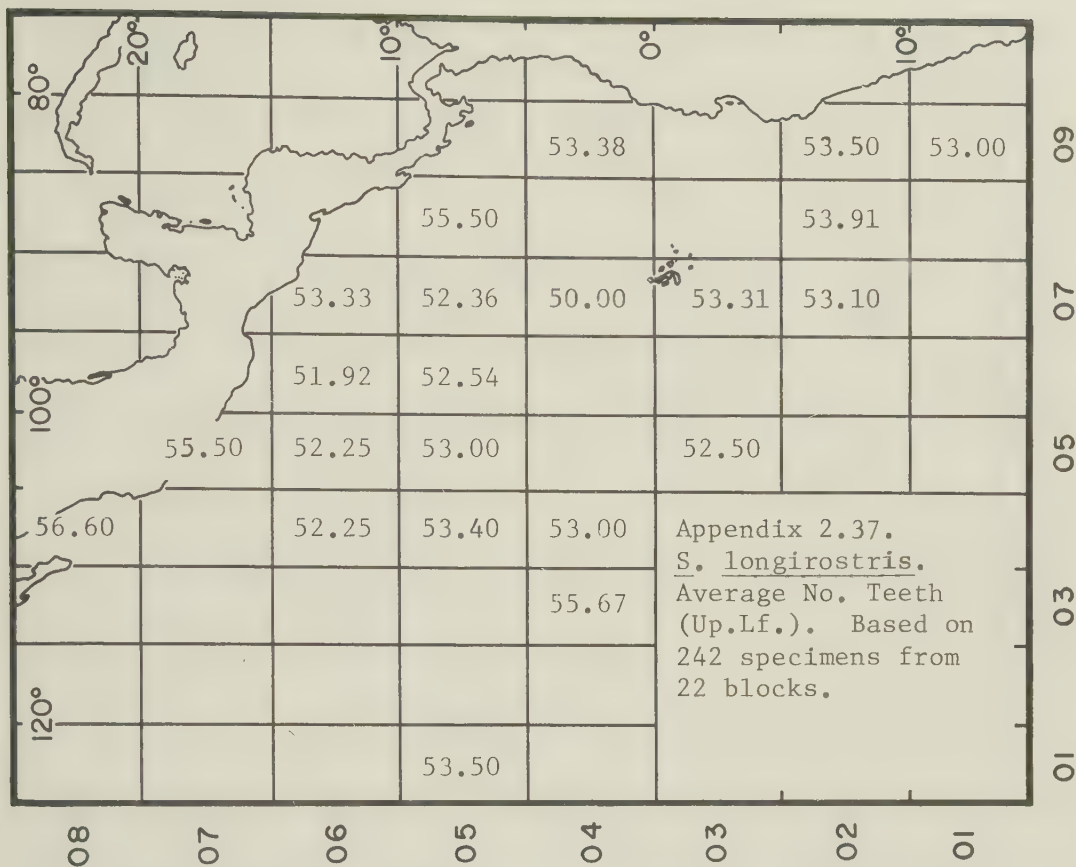


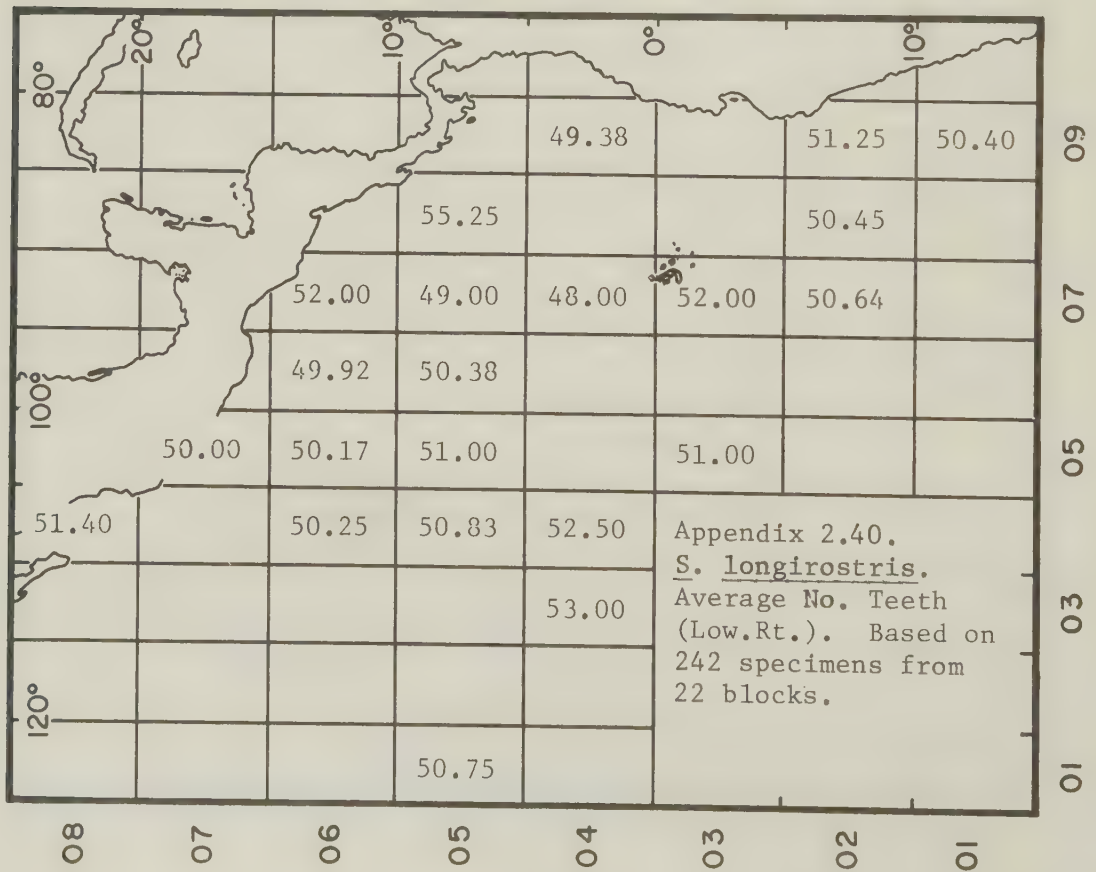
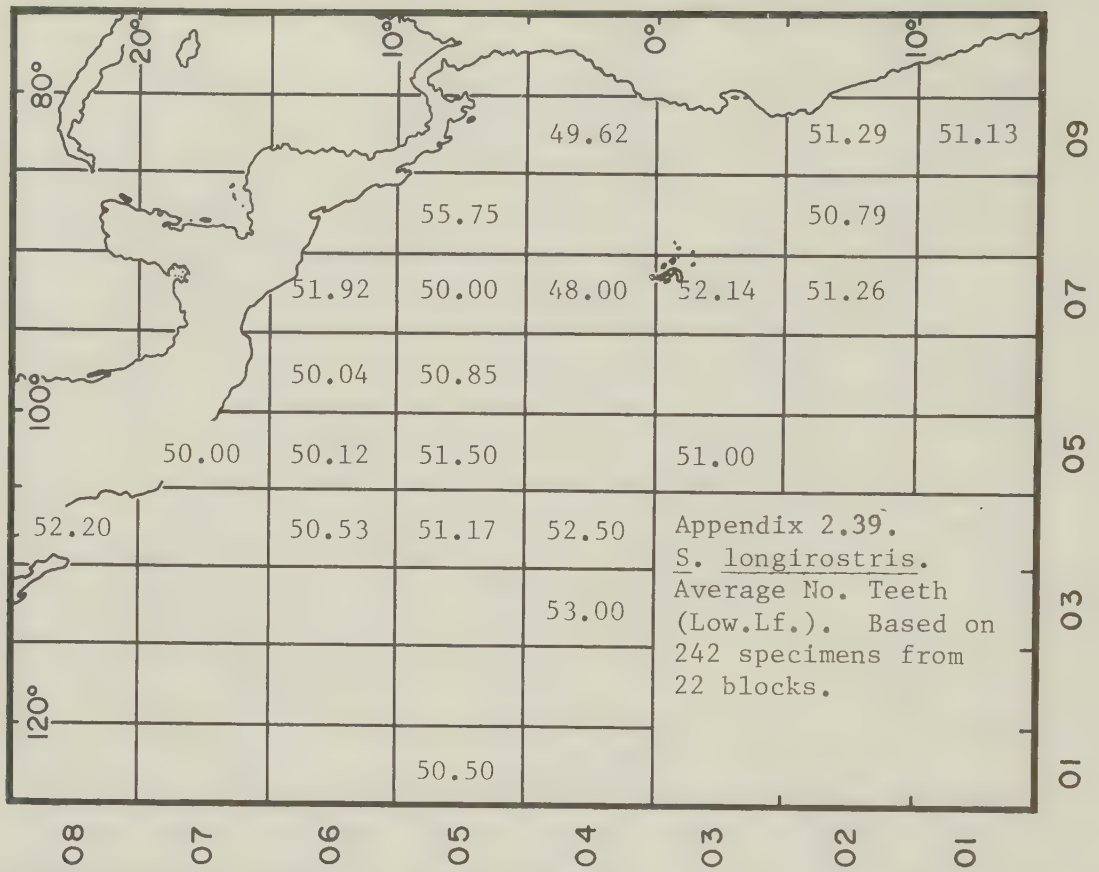


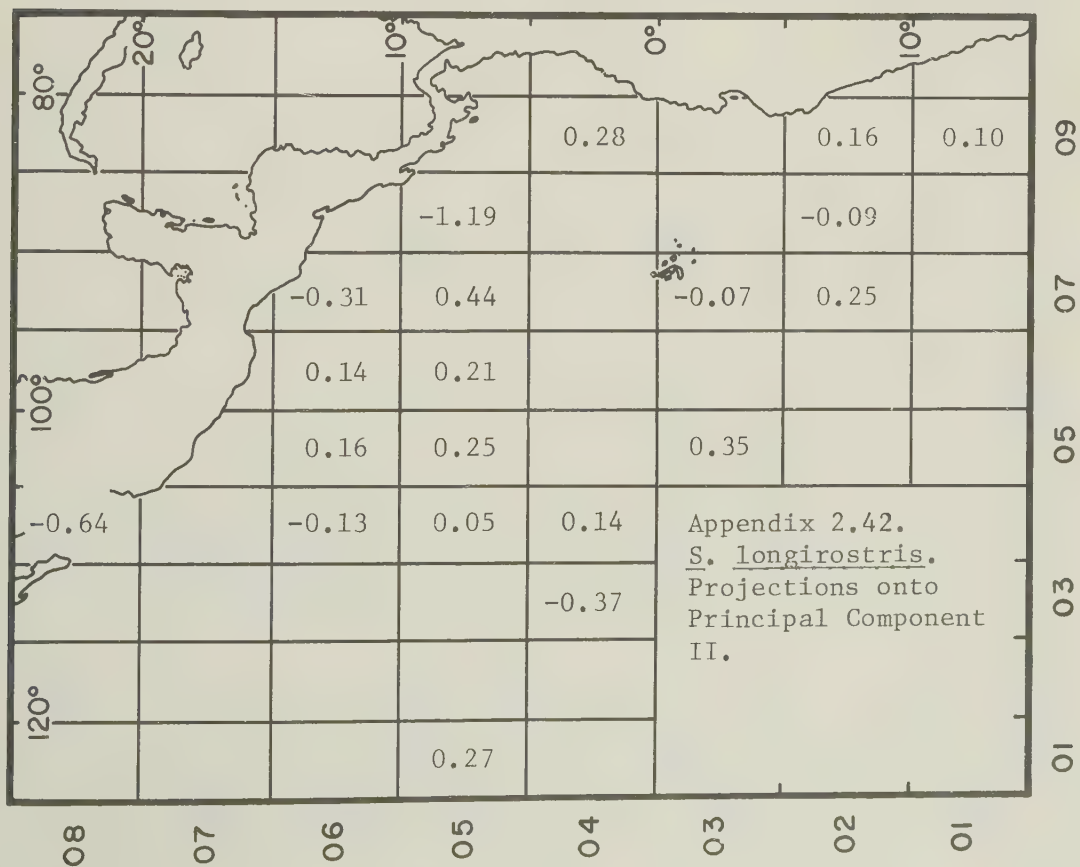
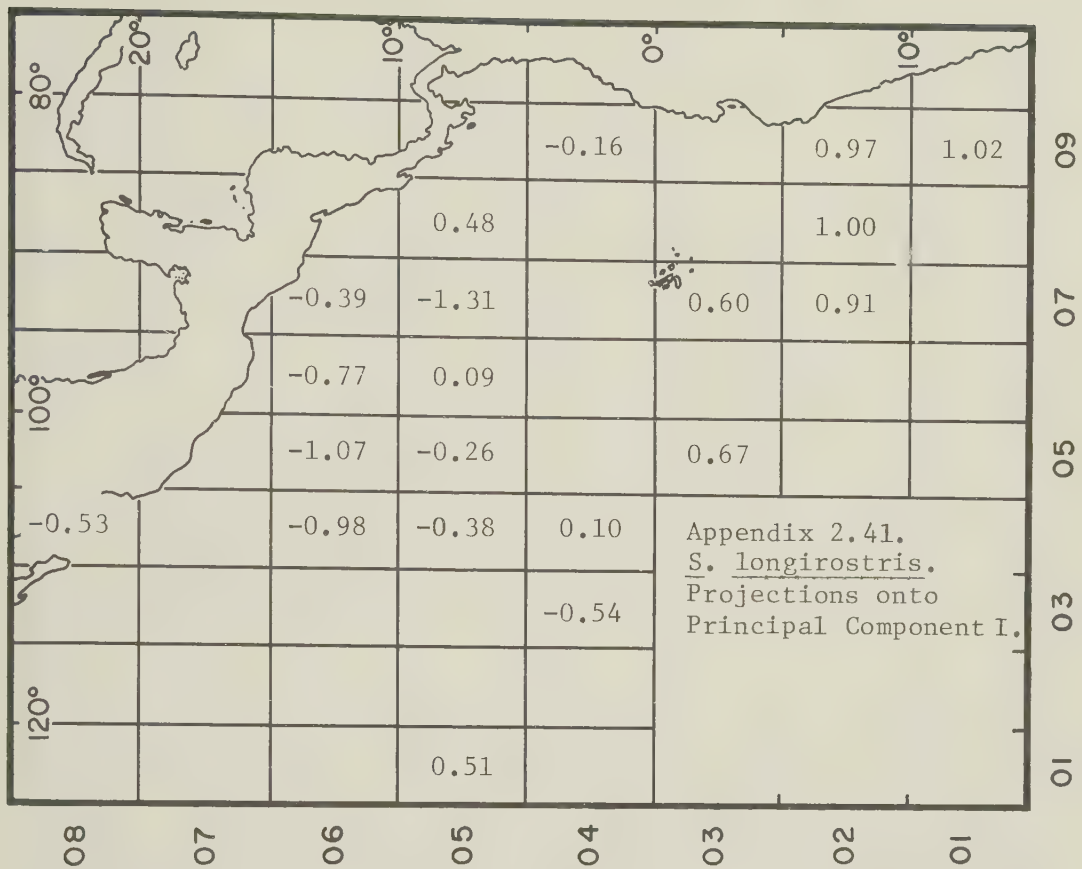


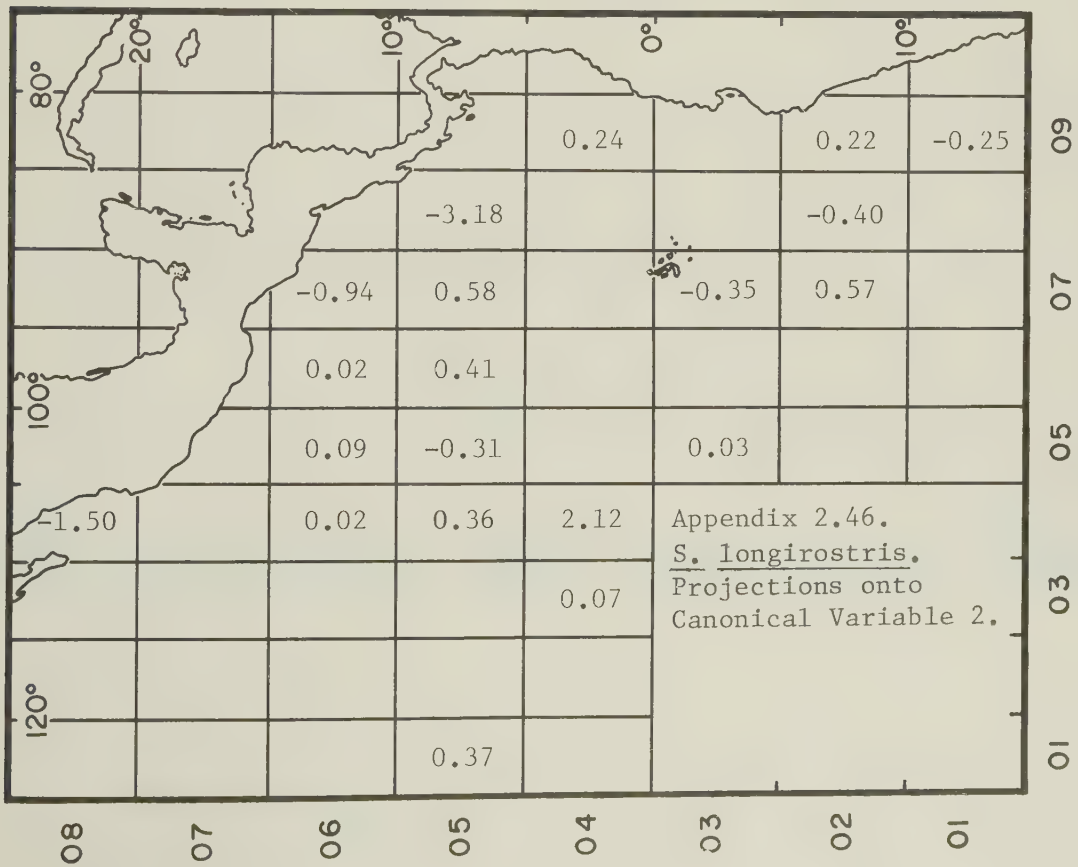
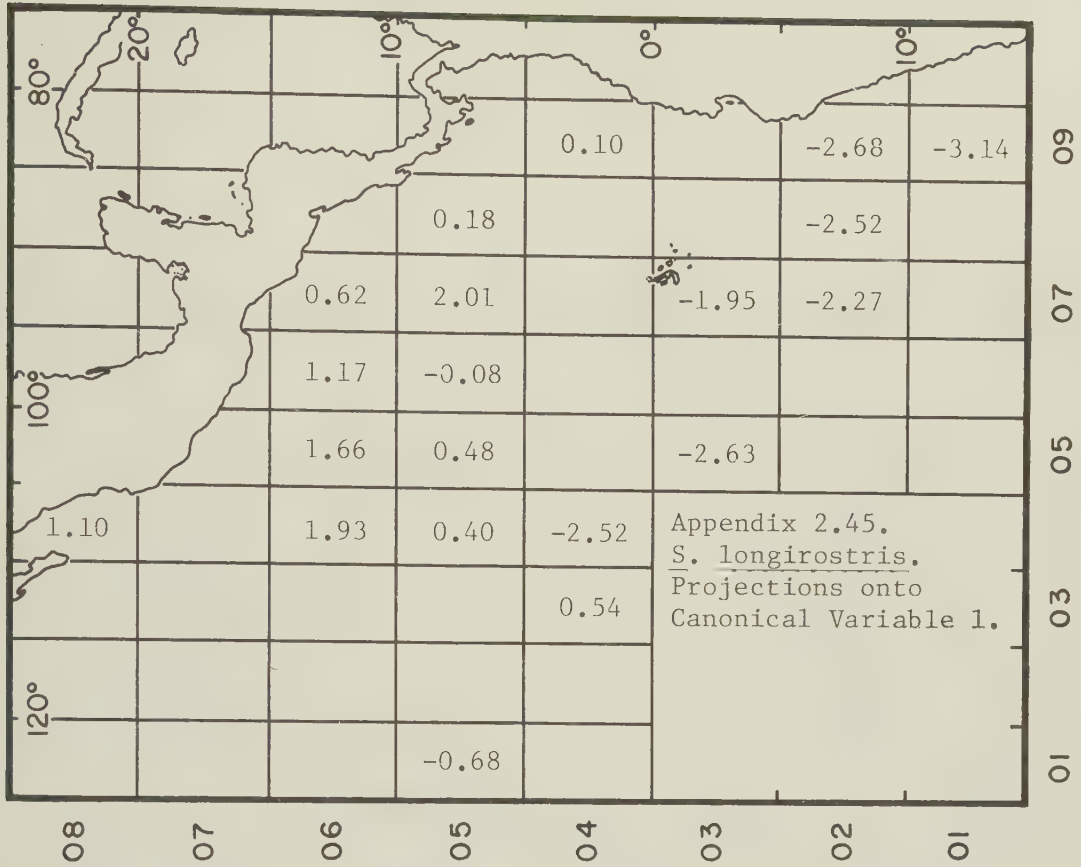


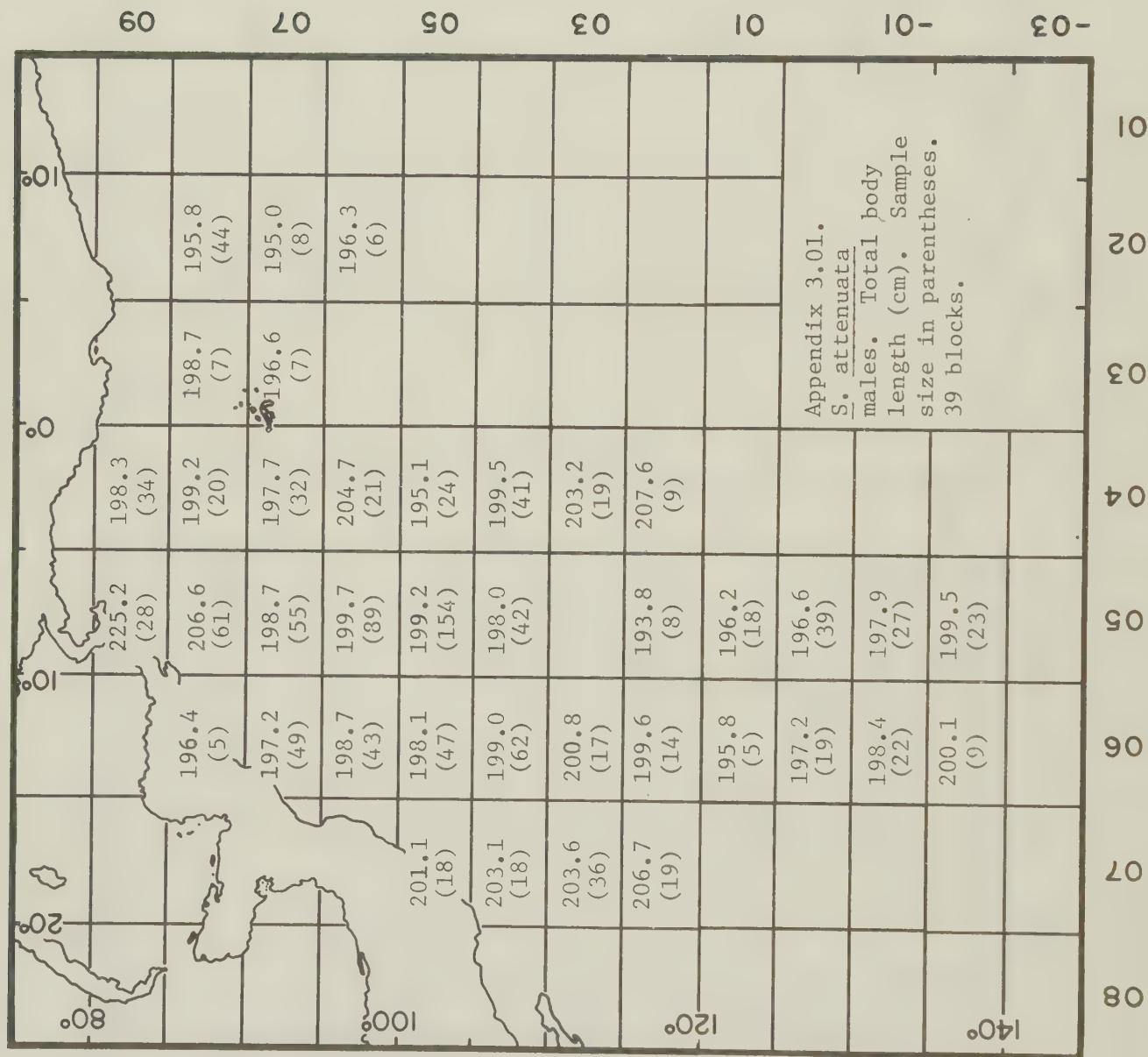












08	07	06	05	04	03			02	01
140°		187.0 (40)	186.5 (51)						Appendix 3.02. <u>S. attenuata</u> females. Total body length (cm). Sample size in parentheses. 47 blocks.
		187.6 (60)	184.3 (63)						
		187.1 (46)	186.3 (93)						
		184.4 (9)	184.8 (59)	188.0 (9)					
	189.9 (7)	184.4 (9)	184.8 (59)	188.0 (9)					
120°	189.9 (39)	186.7 (53)	185.4 (16)	190.5 (29)					
	189.7 (129)	188.4 (68)	187.4 (18)	187.4 (49)					
	190.8 (70)	188.1 (264)	187.7 (225)	186.4 (82)					
	187.3 (30)	187.4 (180)	185.9 (351)	187.7 (63)	188.0 (13)				
	188.0 (5)	188.6 (160)	187.8 (345)	187.5 (70)	185.2 (10)				
		187.5 (191)	187.8 (179)	185.8 (92)	185.1 (77)	184.3 (37)			
		180.8 (9)	191.0 (109)	187.0 (68)	185.6 (37)	185.3 (115)	183.7 (10)		
			204.2 (80)	189.3 (60)	189.3 (11)				
				192.8 (5)					
80°									

09

07

05

03

01

-01

-03

